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Assessment Methodology for Integrated Helmet and Display Systems in Rotary-wing Aircraft

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The U.S. Army is moving towards a trend of using helmet mounted displays in all rotary-wing aircraft. Such devices are integrated systems consisting of the basic helmet, an optical display, eye protection, and a head tracker. This report provides a comprehensive methodology for testing all aspects of such integrated helmet and display systems. The assessment methodology encompasses both laboratory and in-flight evaluations. The major evaluation areas for the laboratory assessment are optical/visual, biodynamic, and acoustical. The in-flight evaluation assesses flight performance and logistical supportability. In addition, human factors and safety issues are addressed.

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III. Acknowledgments

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IV. Preface

The laboratory assessment methodology was developed by Mr. Joseph L. Haley, Jr., Mr. B. Joseph McEntire, and Mr. Joseph R. Licina for biodynamics; Mr. Ben T. Mozo for acoustics; and Dr. William E. McLean and Mr. Clarence E. Rash for vision. The in-flight laboratory assessment methodology was developed by Mr. L. Wayne Richardson of U.S. Army Aviation Technical Test Center, Fort Rucker, Alabama. This project was coordinated and the final report was compiled by Mr. Clarence E. Rash.

1. Introduction

Since the introduction of image intensification (I^2) systems into the cockpit during the 1970s, the use of helmet-mounted devices for pilotage and fire control has been the trend in U.S. Army aviation. The U.S. Army fields two aviation utilized helmet-mounted systems based on the image intensifier tube. The first is known as the AN/PVS-5 Series Night Vision Goggle (NVG) which uses second generation image intensifier tubes (Figure 1). The second, known as the AN/AVS-6 Aviator's Night Vision Imaging System (ANVIS) (Figure 2), uses third generation tubes. Both systems are imaging devices that amplify low-level ambient light reflected from objects. The amplified image is presented on a phosphor screen. The ANVIS and NVG use two image intensifier tubes to form a binocular device which attaches to the standard aviator's helmet (Figure 3).

In the Army's most recent production aircraft, the AH-64 Apache helicopter, the concept of an integrated helmet and display is used. The helmet and display were developed as a system to ensure optimal performance. Known as the Integrated Helmet and Display Sighting System (IHADSS), the system receives its input from a forward-looking infrared (FLIR) thermal imaging sensor, either the Pilot's Night Vision System (PNVS) used for pilotage or the Target Acquisition and Designation System (TADS), located on the nose of the aircraft (Figure 4). The direction of the sensor's line-of-sight (LOS) is slaved to the head motion of the aviator. The display is a miniature (1-inch diameter) cathode-ray-tube (CRT) which produces the image of what the sensor "sees" within its 30 by 40 degree field-of-view (FOV) . Imagery produced on the CRT is relayed optically through a series of lens elements and reflected off a beamsplitter and into the aviator's eye. The beamsplitter also allows for see-through capability. The CRT and relay optics, referred to as the Helmet Display Unit (HDU) (Figure 5), are mounted on the right side of the helmet, providing imagery monocularly (Figure 4).

As mentioned above, the trend for U.S. Army aviation is toward the development and fielding of integrated systems which combine the historical functions of the basic helmet, e.g., impact protection, noise attenuation, communication, etc., with the functions of a display which provides pilotage and fire control information. Programs which have developed such systems include the Aircrew Integrated Helmet System (AIHS) program and the Helmet Integrated Display Sighting System (HIDSS) program. The HIDSS program is in support of the RAH-66 Comanche attack helicopter program.

The development of these integrated helmet and display systems (IHDS) requires a specialized methodology and new ways to assess their performance (Rash et al., 1987ab; Rash and Martin, 1988; Rash, Verona, and Crowley, 1990). The goal of this paper is to provide guidelines for performing evaluations of these new integrated designs. This document includes methodology used in acceptance testing of the IHADSS (Rash et al., 1984; Rash et al., 1987ab), as well as methodology proposed to address issues unique to more novel IHDS approaches (Barson et al., 1988).

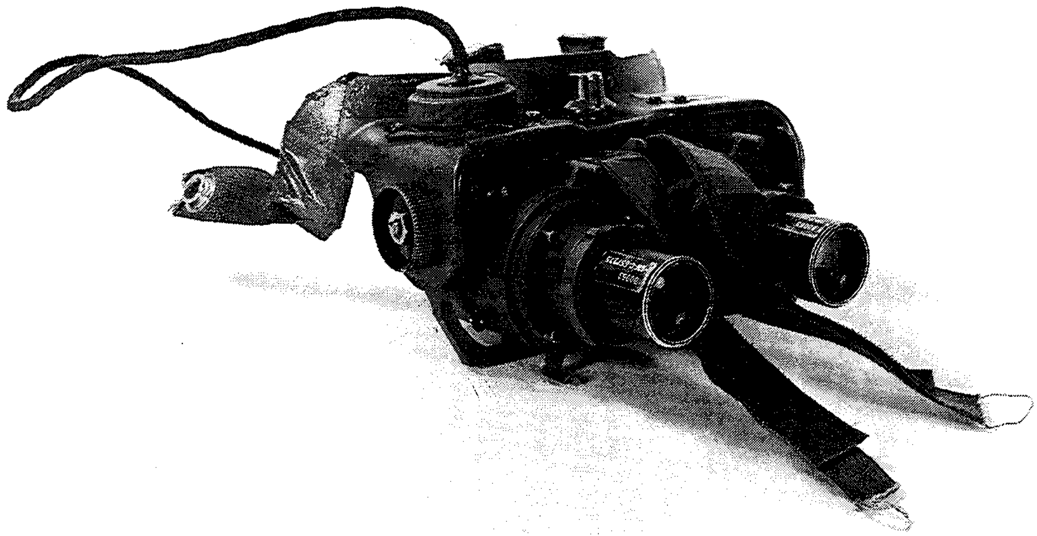

Figure 1. The AN/PVS-5 series night vision goggle.

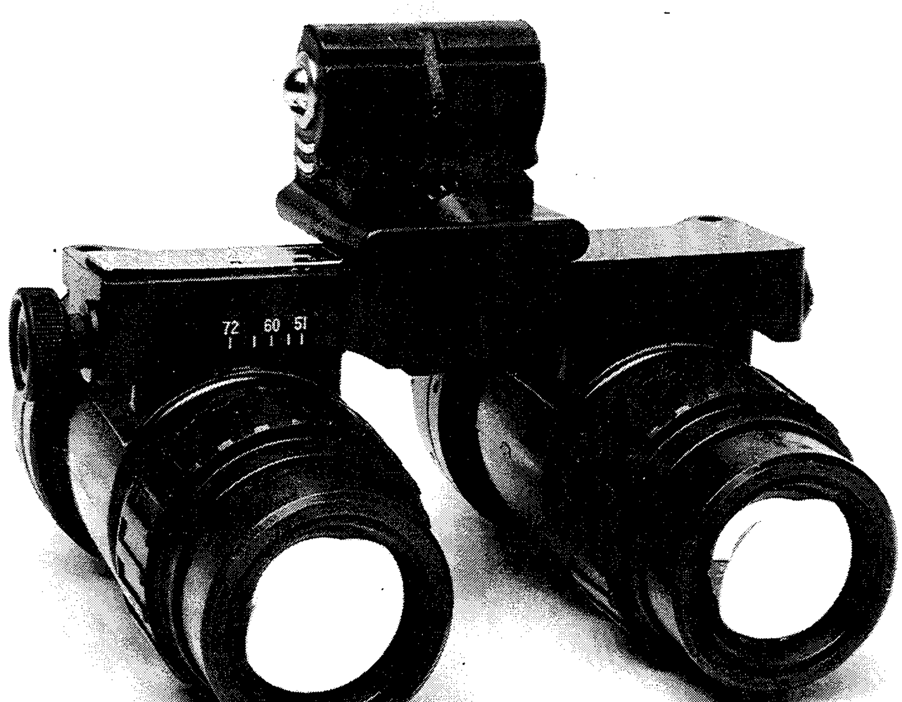

Figure 2. AN/AVS-6 Aviator's Night Vision Imaging System.

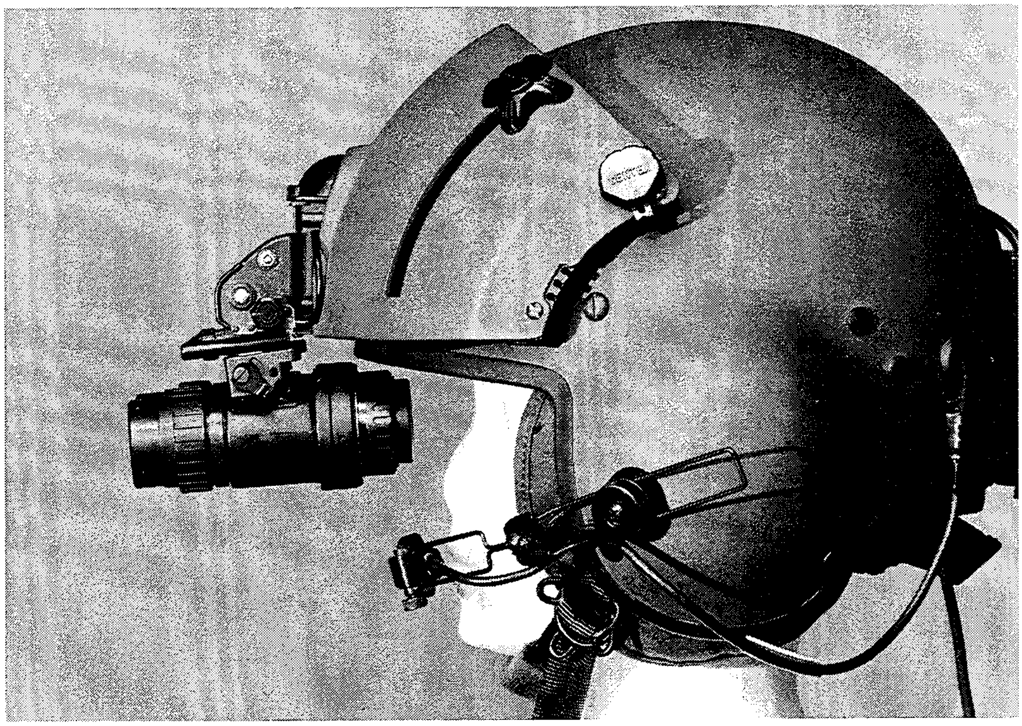

Figure 3. Helmet mounting of the Aviator's Night Vision Imaging System (ANVIS).

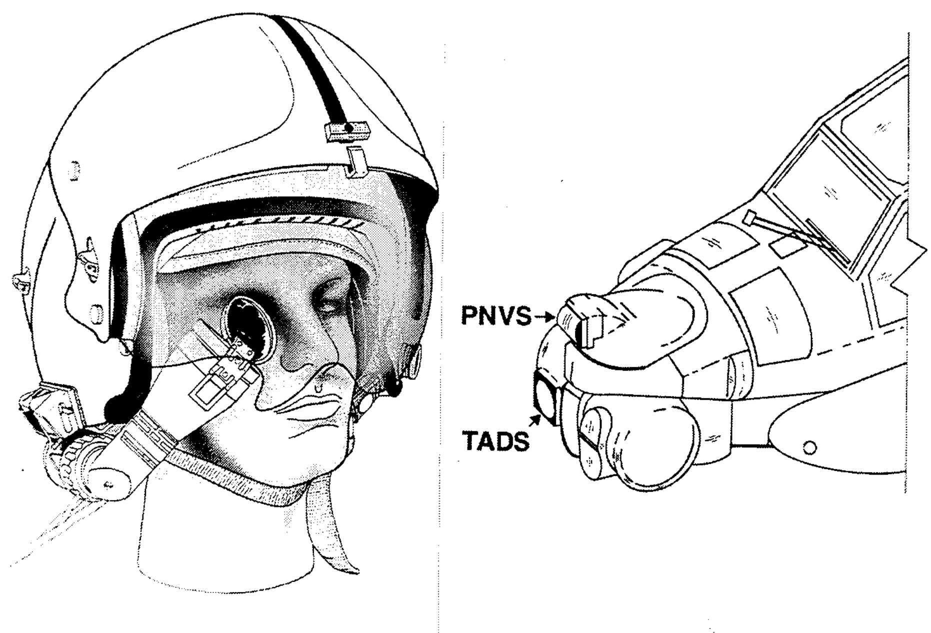

Figure 4. AH-64 helicopter with nose-mounted thermal sensor (PNVS) at right and the Integrated Helmet and Display Sighting System (IHADSS) at left.

The tests presented below address parameters related directly to user performance, health hazards, safety, and human factors. Test parameters related to engineering manufacturing parameters, e.g., power rating, voltage regulation, cooling requirements, wire/cable tensile strength, analog/digital interfaces, etc., generally are not addressed for the emphasis is placed on user performance. The tests presented in the following sections are not all inclusive. Unique design characteristics may require additional tests.

2. Scope

An integrated helmet and display design is comprised of five functional subsystems: (1) the helmet which provides head protection, system suspension and retention, noise attenuation, and interfacing provisions for system components, (2) the display and associated relay optics which present the imagery and symbology required for pilotage and fire control, (3) the head tracking/aiming system which controls sensor and weapon direction, (4) eye protection against sun, wind, dust, ballistic particles, and directed energy (Figure 6), and (5) communication.

In order to define a realistic assessment methodology, it is necessary to limit the scope of this paper. To accomplish this, the assessment methodology described herein makes the following design assumptions: (1) the system is designed for use in rotary-wing aircraft, (2) the primary imagery source is a cathode-ray-tube or image intensification tube, (3) the system produces virtual imagery only, (4) the optical design allows for see-through vision, and (5) there are no performance degradations resulting from the interfacing of the IHDS to the fire control system.

The assessment methodology encompasses both laboratory and in-flight evaluations. The developed methodology is expected to be applicable to any of the four primary stages of system development: concept exploration, demonstration and validation, full scale development, and production. Five strategies are employed to fully develop the required methodology. These strategies are: (1) a system operational assessment, (2) a Health Hazard Assessment (HHA), (3) a Human Factors Engineering Assessment (HFEA), (4) a Systems Safety Assessment (SSA), and (5) a manpower, personnel, and training assessment. The SSA, HHA, and manpower, personnel, and training assessments collectively comprise the major elements of the U.S. Army's Manpower and Personnel Integration (MANPRINT) program. This program emphasizes the integration of human considerations into the design and development of materiel systems (Department of the Army, 1987).

The system operational assessment evaluates the salient characteristics of the proposed system which impact user performance. These characteristics may pertain to the system as a whole or to a specific component of the system. The major evaluation areas for the laboratory assessment are: (1) optical/visual, (2) biodynamic, and (3) acoustical.

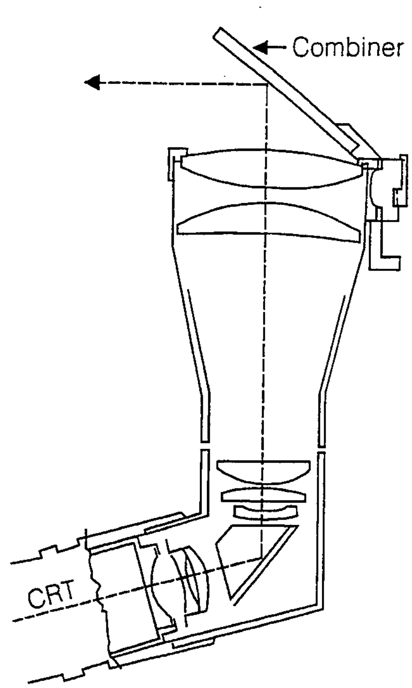

Figure 5. Helmet Display Unit (HDU).

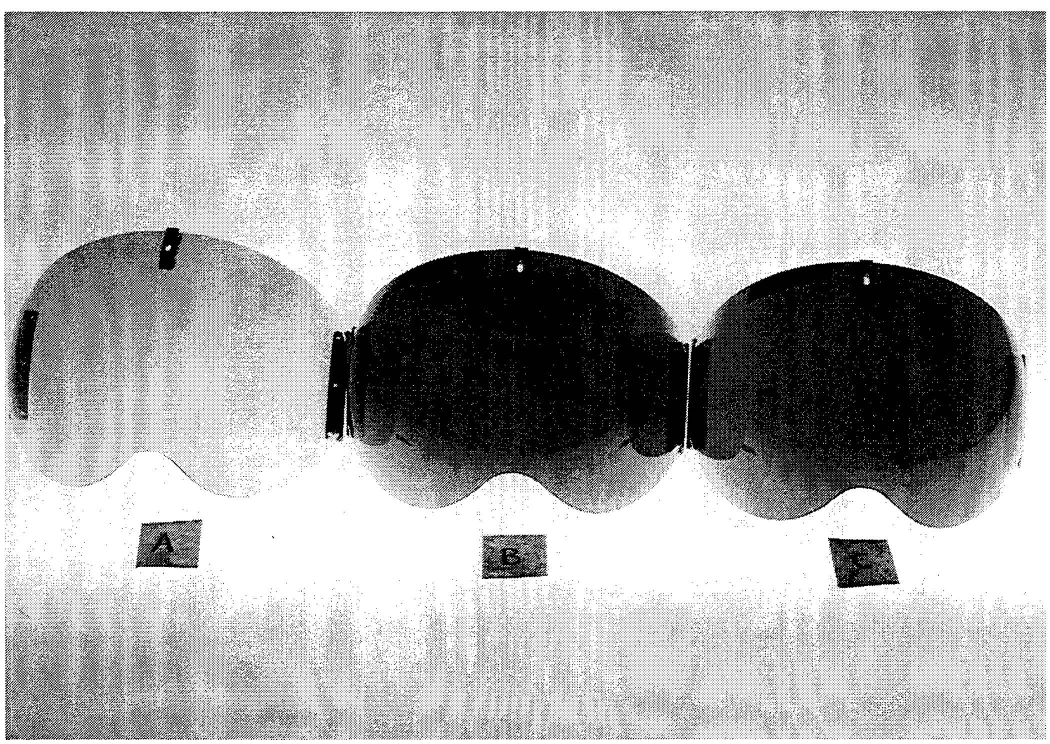

Figure 6. Eye protection as (a) clear, (b) tinted, and (c) laser visors.

The optical/visual assessment encompasses the optical characteristics of the image generation subsystem (display), which is generally a miniature cathode-ray-tube and/or image intensification tube and the visual performance parameters associated with the interface of the user and the display. Most of the presented methodology may be applicable, either directly or with modification) to display based on flat panel technologies, e.g., liquid crystal, plasma, etc.

The Health Hazard Assessment (HHA) identifies risks to the health and effectiveness of personnel who test, use, and maintain Army systems. These hazards can arise from characteristics of the system itself or from the environment in which it operates. These hazards are generally classed into the following major hazard categories: mechanical forces, chemical substances, biological substances, radiation, electricity, and environmental extremes (Leibrecht, 1990). The HHA is conducted in accordance with U. S. Army Regulation (AR) 40-10, Health hazard assessment program in support of the Army materiel acquisition decision process.

The Human Factors Engineering Assessment (HFEA) evaluates candidate systems with regard to compliance with acceptable human engineering design criteria, principles, and practices. Its goals are to maximize user performance and to minimize personnel requirements, skill levels, and training time by ensuring optimal integration of man and machine. AR 602-1, Human factors engineering program, and Military Standard (MIL-STD)-1472D, Human engineering design criteria for military systems, equipment and facilities, provide the guidelines for the HFEA. MIL-HDBK-759A(MI), Human factors engineering design for Army materiel, establishes general data and specific criteria for human factors design and development.

The System Safety Assessment (SSA) is conducted using guidance provided in AR 385-16, System safety engineering and management and Military Standard 882B, System safety program requirements. The SSA addresses safety and health hazards, overlapping many issues addressed by the HHA. Data collected for the Human Factors Engineering Assessment is also applicable to the SSA. However, the scope is expanded to encompass safety requirements and training. In addition, the SSA documents the occurrence, investigation, and proposed correction of accidents or potential accidents associated with the system.

A manpower, personnel, and training assessment identifies the number, type, and skill level of personnel required for safe and effective operation and maintainability of a candidate system. It also identifies the amount and level of personnel training required for safe and efficient system operation.

Historically, the laboratory and in-flight assessments of developmental integrated helmet and display systems have been conducted independently. This approach is adopted in the presentation of the following methodology. The laboratory methodology is presented first, followed by the in-flight methodology. It should be noted that depending on the phase of development of the test system, various elements of the laboratory or in-flight methodologies may not be applicable for all evaluations.

3. Laboratory assessment

3.1. System operational assessment

3.1.1. Introduction

Evaluation for the system operational assessment is categorized first as: (1) materiel inspection, (2) optical/visual (pertaining to optical and visual performance characteristics), (3) biodynamic (relating to the effects of velocity, acceleration, force, etc.), or (4) acoustical (pertaining to communication and sound attenuation). Testing then is further categorized as relating to the total Integrated Helmet and Display System or to a specific subsystem (e.g., protective helmet, display, head tracking/aiming hardware, or eye protective devices), or component (e.g., visor, earcup, chinstrap, etc.). Specific tests relate to individual characteristics which are to be evaluated.

Due to the complexity, nature, and cost of the hardware comprising the IHDS, adequate sample size to ensure statistical confidence in the test data is usually not available. Therefore, conclusions based on a limited sample size should be considered indicative, rather than definitive.

3.1.2. Materiel inspection

When hardware samples of IHDS total system, subsystems, or components are received for assessment, an inspection of such devices shall be performed. The objectives of the inspection are: a) to document the condition of the shipping container upon arrival, b) to identify and document the quantity and type of devices received, and c) to identify and document damaged subsystems/ components or missing elements such as fasteners, connectors, cables, etc.

The test items will be unpacked, inventoried, and compared to the shipping documents for verification. A Laboratory Evaluation Initial Inspection Checklist (Appendix 3) will be completed. Shortages and damage will be recorded and reported as appropriate. Photographs will be taken for documentation, as required.

Pretest services and/or operational checks will be accomplished in accordance with instructions provided. The test items will be considered ready for test if there are no uncorrected discrepancies that preclude initiation of test.

3.1.3. Optical/visual

Optical/visual testing is applicable to the IHDS as a total system and to the image generation and eye protection subsystems. The image generation subsystem is considered to be a helmet-mounted display (HMD) which consists of a) the miniature cathode-ray-tube and/or image intensification tube which produces the imagery and b) the relay optics and eyepiece which present the imagery generated to the eye. (Flat-panel technology image sources, e.g., liquid crystal, plasma, electroluminescence, etc. are not addressed in this paper. Their omission is based on the lack of data

addressing flat-panel technology operating characteristics, flat-panel display image quality figures-of-merit, and the correlation of these parameters to human visual performance.) The eye protection subsystem may be clear, sun, and directed energy protective visors and/or a nuclear flash-blindness protective device (NFPD). The optical/visual system and subsystem/component test parameters are presented in Table 1. For designs where the image intensification tubes are helmet-mounted and physical measurement is not unduly restrictive, these listed parameters include the operating characteristics of the image intensification tubes themselves. As a rule, when pilotage imagery is provided by helmet-mounted image intensification tubes, the IHDS performance (i.e., image quality) shall not be compromised by image intensification performance with respect to signal-to-noise ratio, gain, sensitivity, or presence of tube defects (e.g., as fixed pattern noise, white spots, etc.). In designs where the image intensification imagery is electro-optically converted to video (e.g., by charge-coupled device cameras) and displayed on CRTs, evaluations shall be performed for both FLIR and I^2 CRT imagery.

The optical/visual test parameters selected for evaluating the IHDS as a system, subsystem, and/or individual component are those that have been previously identified as potential factors affecting visual performance. However, many of the parameter values have not been quantified with performance for all the intended tasks (pilotage, navigation, target detection, etc.). The evaluation of the combination of all the possible parameter values on performance would be a time prohibitive task. Therefore, performance criteria presented here for individual tests are based on current accepted principles, military specifications, and industrial requirements. Alternative criteria may be applied. In all cases, criteria contractually required by specification documents take precedence.

In a similar fashion, the procedures described are only one of several possible acceptable methods for measuring a specific parameter. Where alternate apparatus and procedures are used, they each should have a resolution and repeatability equal to or greater than the values stated in the respective sections. When possible, each procedure and apparatus shall be calibrated using repeated measurements of a known standard. A minimum of five measurements will be used for the calibration procedure with ten being preferred. Means and standard deviations of the calibration procedures will be recorded for each optical/visual parameter.

Since visual performance depends on the user being part of the loop, all testing should attempt to perform measurements "as seen by the observer (ASBO)." This observer is assumed to have approximately a 5-millimeter (mm) diameter pupil properly positioned at the exit pupil and aligned with the designed "line-of-sight (LOS)" along the right and left IHDS optical axes (for biocular/binocular systems). Also it is assumed the observer will rotate his direction of gaze through approximately 20 degrees in all meridians from the central line-of-sight.

Table 1.

Optical/visual test parameters

Test	Section
System	
Visual field	3.1.3.1.1.
Spectral transmittance	3.1.3.1.2.
Physical eye-relief	3.1.3.1.3
Interpupillary distance range	3.1.3.1.4
Luminous transmittance	3.1.3.1.5
Chromaticity	3.1.3.1.6.
Neutrality	3.1.3.1.7.
Prismatic deviation	3.1.3.1.8.
Refractive power	3.1.3.1.9.
Cockpit display emission transmittance	3.1.3.1.10.
Display	
Field-of-view	3.1.3.2.1.
Image overlap	3.1.3.2.2.
Resolution (visual acuity)	3.1.3.2.3.
Extraneous reflections	3.1.3.2.4.
Luminance range	3.1.3.2.5.
Grey levels	3.1.3.2.6.
Image luminance disparity	3.1.3.2.7.
Chromatic aberration	3.1.3.2.8.
Contrast ratio	3.1.3.2.9.
Exit pupil size	3.1.3.2.10.
Eye relief	3.1.3.2.11.
Focus range	3.1.3.2.12.
Spherical/astigmatic aberrations	3.1.3.2.13.
Image rotation	3.1.3.2.14.
Image size disparity	3.1.3.2.15.
Vertical and horizontal image alignment	3.1.3.2.16.
Distortion	3.1.3.2.17.
Luminance uniformity	3.1.3.2.18.
Static MTF	3.1.3.2.19.
Dynamic MTF	3.1.3.2.20.

Table 1 (continued).

Optical/visual test parameters

Test	System
Protective visors	
Spectral transmittance	3.1.3.2.21.
Refractive power	3.1.3.2.22.
Prismatic deviation	3.1.3.2.23.
Haze	3.1.3.2.24.
Distortion	3.1.3.2.25.
Color discrimination	3.1.3.2.26.
Optical density	3.1.3.2.27.
Abrasion resistance	3.1.3.2.28.
Luminous transmittance	3.1.3.2.29.
Ultraviolet transmittance	3.1.3.2.30.
Neutrality	3.1.3.2.31.
Chromaticity	3.1.3.2.32.
Visual defects	3.1.3.2.33.
Nuclear flashblindness protective devices	
Luminous transmittance	3.1.3.2.34.
Distortion	3.1.3.2.35.
Prismatic deviation	3.1.3.2.36.
Refractive power	3.1.3.2.37.
Optical density	3.1.3.2.38.

3.1.3.1. Optical/visual system tests

The following tests are applicable to the total system. A specific test may be performed for multiple system configurations. Where applicable all operational combinations of the display optics, visor(s), nuclear flashblindness protective device (NFPD), and ancillary devices shall be tested, as required.

3.1.3.1.1. Visual field

3.1.3.1.1.1. Objective

To determine the area or extent of physical space visible to the user's unaided eyes while wearing the IHDS. To identify the presence of system visual obstructions. Visual field will be

measured for the IHDS for all applicable configurations, including combinations with nuclear, biological, and chemical, (NBC) and oxygen masks.

3.1.3.1.1.2. Criteria

From the forward facing design eye position, the available unaided visual field shall encompass all cockpit master warning indicator lights. The unaided visual field shall permit viewing of all head down displays and flight instruments without excessive head movement. Reduction in visual field due to system obstructions shall be minimized.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.1.1.3. Apparatus

Testing is performed using a perimeter which has been modified to provide fixed positioning of test subjects wearing the IHDS (Figure 7). The perimeter is capable of lateral alignment of subject's head to compensate for subject's inter-pupillary distance (IPD) for measurement of monocular fields.

3.1.3.1.1.4. Procedure

A high contrast (minimum target/background ratio of 100:1) white light target (subtending 10-20 arcminutes) is advanced along specified meridians until the subject indicates detection. (Subject is advised of direction of stimulus and is allowed movement in the direction of the stimuli.) This position is marked and recorded. Measurements are obtained at 15 degree intervals for a full 360 degrees while subject is fixating forward. Background luminance is between 1-10 footlamberts (fL).

Also measured are the subject's interpupillary distance and physical eye relief.

3.1.3.1.1.5. Analytical method

Measured visual field data are presented graphically on a visual field chart (Appendix 4). Comparison is made with data for currently fielded systems. Sources of system obstructions to field are identified and the resulting decrease in visual field is calculated and expressed in percent.

Figure 7. Perimeter for measurement of visual fields.

3.1.3.1.2. **Spectral transmittance**

3.1.3.1.2.1. Objective

To determine the amount of radiant energy transmitted from the outside scene through the IHDS to the eye as a function of wavelength. This test shall be performed for all applicable configurations, e.g., with visors, etc.

3.1.3.1.2.2. Criteria

The spectral transmittance of look-through configurations may vary with wavelength, but shall be such that the requirements for neutrality and ultraviolet transmittance are met.

3.1.3.1.2.3. Apparatus

Measurement shall be performed using a spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557° Kelvin (K)) providing energy over the full wavelength region of interest also is used.

3.1.3.1.2.4. Procedure

Spectroradiometric data are measured at normal incidence over the required wavelength range for a reference tungsten source alone and for the system configuration and light source combination. Standard operating procedures for the spectroradiometer are followed. Data are obtained for all look-through configurations.

3.1.3.1.2.5. Analytical method

Spectral data are presented as transmittance curves as a function of wavelength. These transmittance curves are obtained by performing a division, by wavelength, of the system-source combination data by the source data. The spectral transmittance data are used for calculation of chromaticity (paragraph 3.1.3.1.6.) and neutrality (paragraph 3.1.3.1.7.) parameters.

3.1.3.1.3. Eye clearance distance (Physical eye relief)

3.1.3.1.3.1. Objective

To measure the distance along (or parallel to) the optical axis from the last physical element of the IHDS to the exit pupil and the distances from the exit pupil plane to all IHDS mechanical obstructions within the observer's visual field.

3.1.3.1.3.2. Criterion

The eye clearance distance (also referred to as physical eye relief) shall be sufficient to allow the use of current or planned aviator corrective spectacles, aviator nuclear, biological, and chemical (NBC) protective mask, and oxygen mask without reduction in nonvignetted field-of-view (FOV). A value of 30 mm is recommended.

3.1.3.1.3.3. Apparatus

A millimeter ruler or caliper with 1.0-mm increments or less shall be used. Field-of-view measurements are performed using video signals generated by a Hewlett-Packard* Series 9000 computer used in conjunction with a scan converter. The resultant video signals are input to the IHDS display electronics.

3.1.3.1.3.4. Procedure

Following optimum adjustment, eye clearance distance shall be assessed by measuring the display field-of-view when subject is wearing corrective spectacles, the NBC protective mask, and oxygen mask.

A minimum of five subjects from the intended target population shall be properly fitted with the IHDS. Full field-of-view shall be verified using the procedure of paragraph 3.1.3.2.1.4. Subject shall be fitted with applicable spectacles and the display field-of-view shall be measured. Physical measurements shall be taken for the distance from the subject's cornea to the first physical obstruction along the line-of-sight. This procedure shall be repeated for the NBC and oxygen masks. Additional distance measurements may be taken from appropriate reference points to identified physical obstructions within the subject's visual field.

3.1.3.1.3.5. Analytical method

Measurements of eye clearance distances shall be compared to requirements or goals. The field-of-view for each subject is plotted in the format of Appendix 4. To minimize the effect of display alignment along any given meridian, the data analysis is performed on four pairs of collinear meridians, i.e., 0 and 180, 36 and 216, 90 and 270, and 144 and 324 degrees for a 30 degrees vertical by 40 degrees horizontal field-of-view. (Note: The axes for the diagonal meridians shall correspond to the maximum field-of-view as measured from the design line-of-sight.) For example, misalignment along the horizontal image axis could result in a measured field increase along the 0 degree meridian, but with a corresponding decrease along the collinear 180 degree meridian. This is compensated for by forming a collinear data value from the sum of the 0 and 180 degrees values.

3.1.3.1.4. Interpupillary distance (IPD) range

3.1.3.1.4.1. Objective

To determine for biocular/binocular systems if the optical paths of the display can be adjusted to accommodate the user's dual visual axes. To determine for monocular systems if the optical path can be aligned to the user's visual axis.

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* See manufacturers' list, Appendix 32.

3.1.3.1.4.2. Criteria

IPD or X-axis optical adjustments shall conform to system specifications. Previously accepted values for IPD range are 58 to 72 mm. The full required field-of-view shall be achievable over the full IPD range. A desired design goal is 55 to 75 mm.

3.1.3.1.4.3. Apparatus

Required equipment includes a dioptometer, two thin translucent diffusing screens with center cross, an optical comparator (0.2-mm increments or smaller), an adjustable iris, millimeter ruler or caliper, and optical bench.

Field-of-view measurements shall use video signals generated by a Hewlett-Packard Series 9000 computer used in conjunction with a scan converter. The resultant video signals are input to the IHDS display electronics.

3.1.3.1.4.4. Procedure

The following procedure is applicable to on-axis IHDSs with centered right and left symmetrically shaped exit pupils. Off-axis and nonsymmetrically shaped exit pupil IHDS designs may require alternate procedures suitable to the specific design.

The exit pupils are imaged onto the translucent screens and their centers located using the display exit pupil procedure presented in paragraph 3.1.3.2.10.4. For biocular/binocular systems, the lateral distance between the exit pupil centers is measured at both extremes of IPD settings. For monocular systems, the lateral adjustment range is measured.

Where possible, full display FOV for subjects having extreme minimum and maximum IPDs shall be verified using the procedure in paragraph 3.1.3.2.1.4 (Display field-of-view).

3.1.3.1.4.5. Analytical method

Measured IPD range shall be compared to requirements. Analysis shall be as performed in accordance with paragraph 3.1.3.1.3.5. to verify availability of full field-of-view for all IPD settings.

3.1.3.1.5. System luminous transmittance

3.1.3.1.5.1. Objective

To determine the amount of visible light transmitted from the external scene through the system to the eye under photopic and scotopic conditions, i.e., see-through transmittance. This measurement shall be performed for all possible system optical media combinations.

3.1.3.1.5.2. Criteria

Specific criteria for see-through transmittance should be specified in specification documents. If these criteria are not provided, see-through luminous transmittance shall be specified after a careful trade off analysis between display brightness, aircraft transparency transmittance, and range of background luminances for the intended use of the IHDS. The purpose of see-through vision and display imagery/symbology, e.g., when pilotage is primarily a function of unaided vision and when pilotage is performed primarily with an electro-optical image, should be included in this analysis.

If there are noticeable differences in transmittance with different viewing angles from the line-of-sight (e.g., greater than 50 percent difference between the center and a given angle), then the difference in transmittance between the eyes for a given angle of view shall not exceed 30 percent (0.15 log attenuation) of each other.

3.1.3.1.5.3. Apparatus

Luminous transmittance may be empirically calculated from spectral transmittance data obtained using a spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength region of interest, also is used. Alternatively, a photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert (fL) or less, and photopic and scotopic filters may be used.

3.1.3.1.5.4. Procedure

The test is conducted in a completely dark room. The light source is placed three meters or greater from the IHDS. The assumption is made that the optical channels can be detached from the helmet unit.

When using the photometer, luminance measurements are taken at the center points of the right and left optics, as defined by the lines-of-sight in the "as worn" position. The photometer is placed at the design eye position. Luminance measurements are made with and without each intervening optical component combination. Measurements are made using the photometer's photopic and scotopic filters.

The method described in paragraph 3.1.3.1.2.4. is used to acquire the spectral data when the luminous transmittance is calculated from spectral transmittance data. These data then are weighted using the spectral weighting factors for photopic and scotopic relative spectral luminous efficiencies given in Appendix 5 (Kingslake, 1965; American Institute of Physics Handbook, 1962).

When worn by the evaluator, if there is a noticeable difference in the luminance transmittance through the optical system with different angles of gaze, then the IHDS will be pivoted about the

centers of eye rotation. Luminance measurements are taken at the eight primary meridians at an angle approximately midway between angle from the line-of-sight and the limiting see-through edges of the beamsplitter (combiner).

In either procedure, each measurement consists of reading the luminance (or spectral data) of the reference source, placing the system normal to the optical path, and taking a second reading. The transmittance is calculated by dividing the luminance value obtained without the system optics in place into the value obtained when the optics is in place. For the photometer method, measurements are obtained using the photometer's photopic and scotopic settings.

3.1.3.1.5.5. Analytical method

Calculated see-through transmittance values shall be compared directly to specifications requirements. The photopic and scotopic luminous transmittance will be calculated for Commission Internationale de l'Eclairage (CIE) Source C. Using the photopic and scotopic relative luminous efficiency functions (Appendix 5) and the relative spectral distribution of the CIE Source C given in Appendix 6, the photopic and scotopic luminous transmittances, T_p and T_s respectively, are calculated by:

$$T_p = (1/k) \int_{380}^{780} (T_e)(E_e)(V_p)\, d\lambda$$

for photopic

and

$$T_s = (1/k) \int_{380}^{780} (T_e)(E_e)(V_s)\, d\lambda$$

for scotopic

$$\text{where } k = \int_{380}^{780} (E_e)(V_p)\, d\lambda$$

for photopic

and

$$k = \int_{380}^{780} (E_e)(V_s)\, d\lambda$$

for scotopic

and T_e = spectral transmittance of system by wavelength
E_e = relative spectral radiance of CIE Source C by wavelength
V_p = photopic luminous efficiency by wavelength
V_s = scotopic luminous efficiency by wavelength

Commercially available spectroradiometric software packages may be used to perform calculations.

The resulting transmittance values are compared directly to requirements.

3.1.3.1.6. System chromaticity

3.1.3.1.6.1. Objective

To calculate the chromaticity coordinates of the various combinations of look-through optical elements of IHDS system.

3.1.3.1.6.2. Criterion

The 1931 Commission Internationale de l'Eclairage (CIE) chromaticity coordinates x and y (Wyszecki and Stiles, 1967) shall be within the limits indicated in Figure 8.

3.1.3.1.6.3. Apparatus

A spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength region of interest is required.

3.1.3.1.6.4. Procedure

Spectroradiometric data are measured at normal incidence over the required wavelength range for a reference tungsten source alone and for the system configuration and light source combination. Standard operating procedures for the spectroradiometer are followed. Data are obtained for all applicable configurations.

3.1.3.1.6.5. Analytical method

The chromaticity coordinates x and y are calculated from the spectral transmittance data by the method presented in MIL-V-43511C, paragraph 4.5.9. Using this method, the products of the transmittance data and the CIE tristimulus function values (Appendix 7) are summed in 10 nanometer increments over the wavelength range of 380-780 nanometers (nm). These sums,

designated as X, Y, and Z, are used in the following equations to calculate the chromaticity coordinates (x, y, and z):

$$x = X/(X + Y + Z),\ \ y = Y/(X + Y + Z),\ \text{ and } z = Z/(X + Y + Z).$$

Commercially available spectroradiometric software packages may be used to perform calculations.

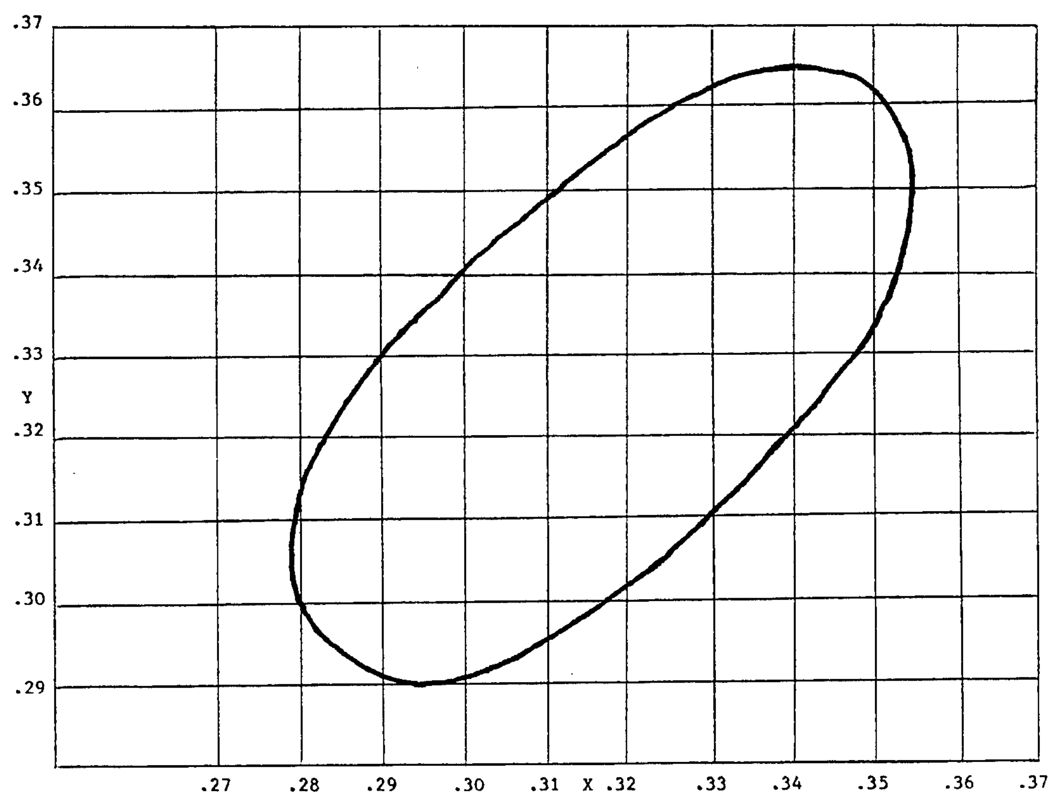


Figure 8. Chromaticity coordinates requirement.

3.1.3.1.7. System neutrality

3.1.3.1.7.1. Objective

To verify a uniform distribution of transmitted energy throughout the visible spectrum (430-730 nm) for the purpose of minimizing color distortion.

3.1.3.1.7.2. Criteria

Aviator color discrimination capability shall not be altered for any look-through configuration. Configurations including directed energy eye protective devices operating in the visible spectrum shall produce minimum degradation of color discrimination.

The spectral transmittance may vary with wavelength between 430 and 730 nm. However, the calculated spectral transmittance deviation (neutrality value) shall be less than 12 percent (except for certain directed energy protective devices).

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.1.7.3. Apparatus

A spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2587°K) providing energy over the full wavelength region of interest is required.

3.1.3.1.7.4. Procedure

Spectroradiometric data are measured at normal incidence over the required wavelength range for a reference tungsten source alone and for the system configuration and light source combination. Standard operating procedures for the spectroradiometer are followed. This procedure shall be performed for all applicable configurations.

3.1.3.1.7.5. Analytical method

The neutrality is calculated by the Judd daylight duplication method. This method requires calculating the average spectral transmittance deviation for nine spectral bands between 430 and 730 (see paragraph 4.5.8. of MIL-V-43511C). Commercially available spectroradiometric software packages may be used to perform calculations.

3.1.3.1.8. System prismatic deviation

3.1.3.1.8.1. Objective

To determine the total prismatic deviation (vertical and horizontal) between pairs of conjugate points of vision through all combinations of visors, combiners, and/or other optical media of the IHDS. On-axis and 20 degrees off-axis measurements shall be made.

3.1.3.1.8.2. Criteria

For vertical prismatic deviation, base up prism shall be designated positive (+) and base down prism shall be designated negative (-). For horizontal prismatic deviation, base out shall be designated positive (+) and base in shall be designated negative (-).

Vertical -- the algebraic difference between the vertical prismatic deviation of the conjugate pairs for the right and left eyes shall be no more than 0.18 diopter nor shall the vertical prism exceed 0.18 diopter at these points.

Horizontal -- the algebraic sum of the horizontal prismatic deviation of the conjugate pairs for the right and left eyes shall not exceed 0.50 diopter nor be less than -0.18 diopter. The absolute algebraic difference between the horizontal deviation at the center points shall not exceed 0.18 diopter.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.1.8.3. Apparatus

(a) For on-axis measurements: Double parallel telescopes (4X or greater) with alignment reticles marked in 1 arcminute (0.34 milliradians [mr]) increments or less are used. A real or virtual cross-hair target located 3 meters or greater from the IHDS is also required.

(b) For off-axis measurements: Light projector(s) or laser pointer; small circular or cross-hair target slide; measuring rulers; mounts for mirrors (4), viewing screens, and IHDS, small front surface mirrors (2) with two axes of rotation.

3.1.3.1.8.4. Procedure

(a) On-axis: Locate the exit pupils of each IHDS ocular using the procedure in paragraph 3.1.3.2.10.4. Position the objective lenses of the binocular telescopes at the exit pupil positions of the IHDS. These objective lenses shall be reduced to 10 mm or less using an aperture. Measurements of the location of the test cross-hair target in arcminutes for each right and left ocular are recorded with and without the IHDS in place for both the vertical and horizontal axes.

(b) Off-axis: To measure approximately 20 degrees from the designed line-of-sight for the 8 cardinal meridians, an alternative method is required. Two front surfaced mirrors with 2 axes rotation about the center of the mirrors are mounted at the designed exit pupil points using an equivalent inter-pupillary distance of 65 mm. Below each two-axis rotatable mirror is a second mirror which allows a 90 degree rotation of the projected image. A single slide projector or laser pointer can be aligned with the bottom mirrors such that the projected target is incident to the bottom rotatable mirrors by means of a beamsplitter and front surface mirrors (Figure 9). Dot targets from the slide projector are imaged on a wall or screen a minimum of three meters away. The rotatable mirrors, which represent the locations of the observer's eyes, are moved by tilt and rotation such that the projected targets can be deviated up to 20 degrees from the designed line-of-sight.

Without the IHDS in place, the projected images are aligned at the 8 meridians, 20 degrees off-axis from the line-of-sight. The right and left images shall have parallel paths, assuming the eyes would be converged at infinity. The location of the images are marked on the screen without the IHDS and then with the IHDS. The vertical and horizontal displacements for each eye are recorded.

3.1.3.1.8.5. Analytical method

The vertical prismatic deviation is calculated by determining the algebraic difference between the pairs of conjugate points. The horizontal prismatic deviation is calculated by determining both algebraic sum and difference for the conjugate pairs. Calculated values are compared directly to criteria.

3.1.3.1.9. System refractive power

3.1.3.1.9.1. Objective

To determine the total residual spherical and astigmatic refractive power induced by intervening optical media, e.g., combiners and visors.

3.1.3.1.9.2. Criteria

The total residual refractive power for each optical look-through configuration of the IHDS using look-through vision shall not exceed +0.12 or -0.25 diopter spherical equivalent or 0.25 diopter of cylindrical power.

Where required, additional or alternate criteria from specification documents shall be used for this test.

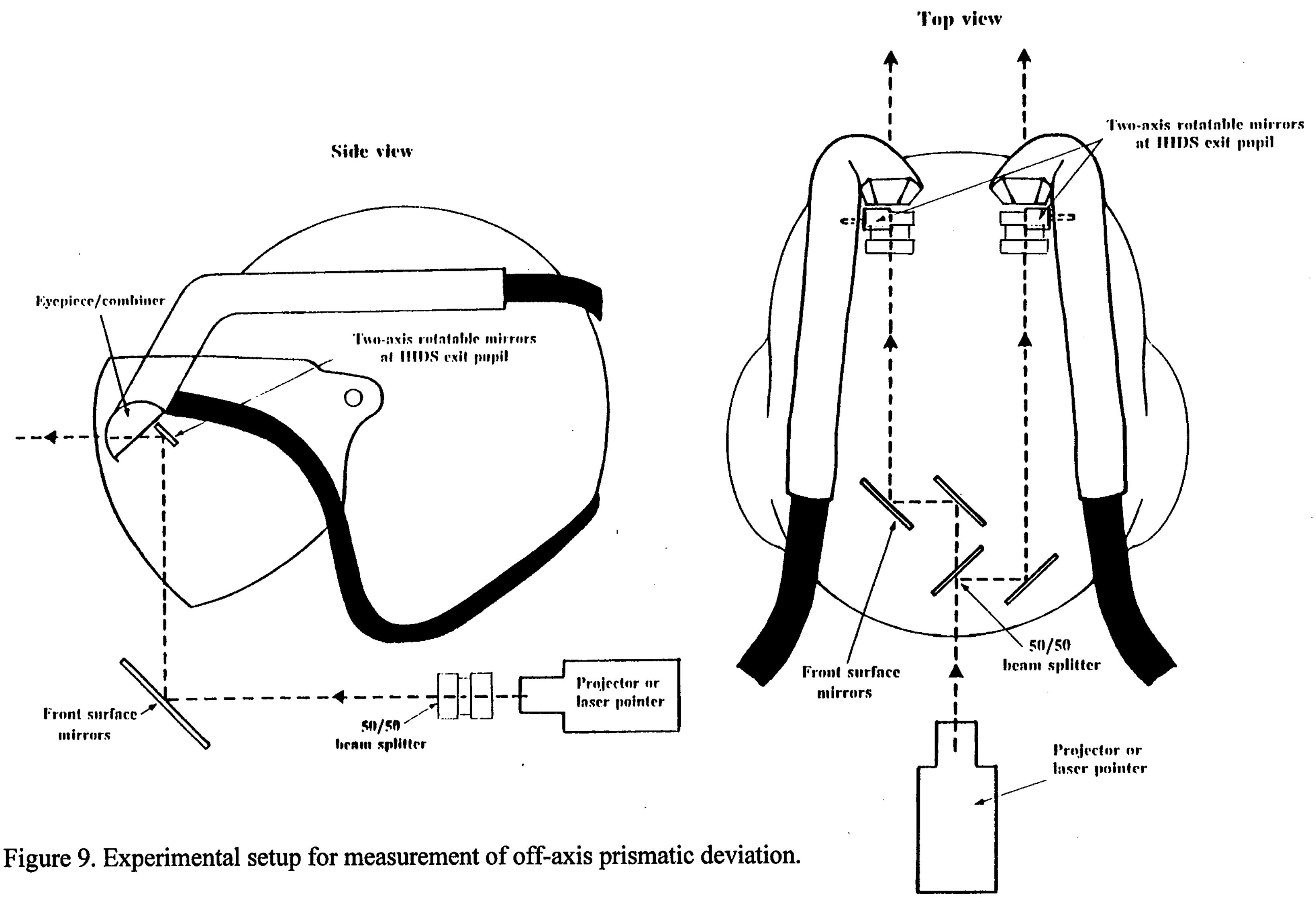


Figure 9. Experimental setup for measurement of off-axis prismatic deviation.

3.1.3.1.9.3. Apparatus

Chart test pattern of a 24-spoke wheel with wheel radius subtending 5 degrees and spoke width equivalent to 1 display pixel width (Figure 10); an 8X telescope/diopterscope with a cross-hair reticle or equivalent; optical bench and mounting hardware. The telescope shall have an adjustable, calibrated focusing eyepiece and the objective lens diameter restricted to approximately 10 mm or less. Apparatus shall be able to measure residual refractive errors in 0.06 diopters or less for spherical and astigmatic (cylindrical) components.

3.1.3.1.9.4. Procedure

The objective lens of the telescope/diopterscope is placed as close as possible to the eye relief point of the IHDS exit pupil. If, due to mechanical obstructions, the position of the telescope is behind the exit pupil, the vertex distance from the exit pupil shall be recorded. The spoke test pattern chart shall be placed approximately 10 feet (3 meters) or greater and at the range used for calibration of the focusing eyepiece of the telescope. Without the display and intervening optics, the eyepiece of the telescope is focused and zeroed using the spoke chart and the internal cross-hair reticle. The HMD then is placed in the mounting hardware with the telescope objective lens at or near the exit pupil of the HMD. Folding mirrors may be required to align the telescope with the designed forward line-of-sight.

The eyepiece of the HMD is focused while the spoke wheel target is being observed. The range of diopter values that allow any spoke to be focused shall be recorded. The difference between these maximum and minimum values and the axes of the spokes are the astigmatic quantities. The residual power is written in standard optical format of sphere, cylinder, and axis.

The IHDS is rotated about the designed eye rotation point and measurements taken at approximately 20 degrees from the center line-of-sight, at the 8 cardinal meridians.

If the combination of visors, combiners, and other intervening optical media can not be measured as a system, the power shall be measured for each subsystem/component using the above procedure and calculating the resultant cylinder and axis by any cross cylinder method.

3.1.3.1.9.5. Analytical method

The measured system refractive power shall be compared directly to the test criteria. If the system refractive power can not be measured directly, then the individual residual refractive powers can be summed using an appropriate cross cylinder calculating method.

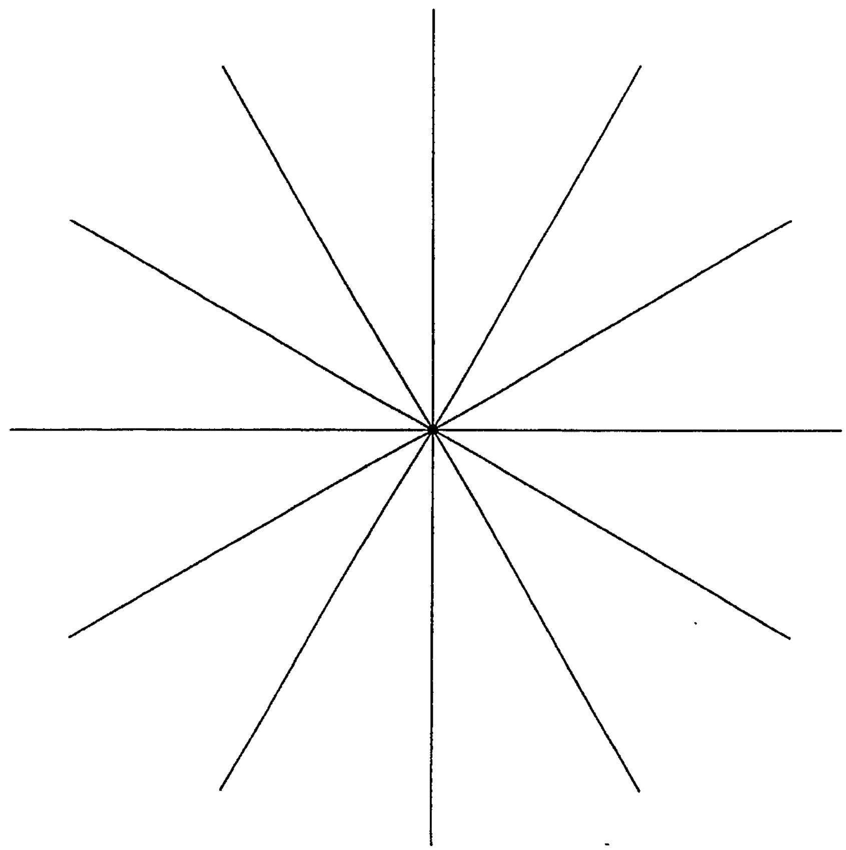


Figure 10. Spoke wheel target for system refractive error test.

3.1.3.1.10. Cockpit display emission transmittance

3.1.3.1.10.1. Objective

To measure the amount of visible light emitted by cockpit displays transmitted through the system to the eye under photopic conditions.

3.1.3.1.10.2. Criterion

When calculated for the spectral distribution of cockpit display emission sources (e.g., CRT phosphors), the luminous transmittance of all look-through optical configurations shall be equal to or greater than 40 percent or as required by specification documents.

3.1.3.1.10.3. Apparatus

A spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0

percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength region of interest is required.

3.1.3.1.10.4. Procedure

Spectroradiometric data are measured at normal incidence over the required wavelength range for a reference tungsten source alone and for the system configuration and light source combination. Standard operating procedures for the spectroradiometer are followed. Data are obtained for all look-through configurations.

For narrow band displays (i.e., P43 phosphor), data shall be collected at suitable wavelength intervals (2-nm interval is recommended for P43).

3.1.3.1.10.5. Analytical method

The spectral transmittance data (T_e) for each of the system see-through configurations are used with the spectral radiance distribution (E_e) of each cockpit display to calculate the photopic luminance transmittance by the equations in paragraph 3.1.3.1.5.5. Commercially available spectroradiometric software packages may be used to perform calculations.

3.1.3.2. Subsystem/component tests

The following tests are applicable to either the display unit and associated image generation components (i.e., CRT and/or I^2 tube), protective visors, or nuclear flashblindness protective devices. Visors are classified as Class I (clear, luminous transmittance not less than 85 percent), Class II (tinted, sun protective, luminous transmittance between 12 and 18 percent), or special class (directed energy protective and other). Unless otherwise specified, the visor(s) shall have 3 areas of vision: (1) the central portion of each optics (right and left) encompassing an area corresponding to 15 degrees about the optical center as subtended at the eye (referred to as critical vision area), (2) the see-through peripheral area beyond the 15 degrees (referred to as noncritical vision area), and (3) outside the area of vision (no optical requirement). The center point of each optic shall be identified as point "C" and defined as the point of intersection of user line-of-sight on the visor. Most visor tests are as described in or adapted from MIL-V-43511C, Visors, flyer's, helmet, polycarbonate.

Criteria cited below for subsystem/component tests may be superseded by criteria for the same test at the system level. For example, visor neutrality criteria stated below in paragraph 3.1.3.2.31.2. is applicable if the visor is the only see-through optical element in a selected IHDS system configuration. If see-through vision involves other optical elements in combination with the visor, then the system neutrality test criteria (paragraph 3.1.3.1.7.) take precedence. For many tests, no system criteria have been developed. For these tests, the test criteria cited at the component and system levels are the same, the component criteria. Therefore, caution must be exercised to ensure final evaluation is based on operational system configurations.

3.1.3.2.1. Display field-of-view

3.1.3.2.1.1. Objective

To determine the size (horizontal and vertical angular subtense to the eye) of the system's displayed imagery at the user-adjusted optimized eye clearance distance and at a 10 mm distance out from the optimized position.

3.1.3.2.1.2. Criteria

The display field-of-view for the pilotage mode shall meet design specifications and match the field-of-view of the pilotage sensor with unity magnification. An increase in 10 mm of eye relief beyond the optimal user selected position shall not decrease field-of-view by a percentage to be determined (TBD).

3.1.3.2.1.3. Apparatus

For CRT imagery, the video signals required for initial alignment and field-of-view stimuli are generated by a Hewlett-Packard Series 9000 computer used in conjunction with a scan converter. The resultant video signals are input to the IHDS display electronics.

For image intensification imagery, a physical target board with a concentric marking pattern is required (Figure 11). The target markings are incremental tic marks inscribed along 8 meridians, 0, 36, 90, 144, 180, 216, 270, and 324 degrees for a 30 degrees vertical by 40 degrees horizontal field-of-view. (Note: The axes for the diagonal meridians shall correspond to the maximum field-of-view as measured from the design line-of-sight.) The concentric markings shall equate to a minimum resolution of 1 degree at the viewing distance of the target board. For a viewing distance of 5 meters (16.4 feet), tic marks must be less than or equal to 10 centimeters. The target board is illuminated by an artificial night sky illumination source.

3.1.3.2.1.4. Procedure

Field-of-view measurements are performed monocularly and combined for biocular or binocular systems. A minimum of three subjects representing a range of IPD values and head dimensions shall be tested.

CRT imagery: Once properly fitted and optically aligned using the manufacturer's recommended procedure, each subject is provided with an alignment pattern which is used to focus, center, and orient the display imagery (Figure 11). The alignment pattern consists of 8 meridional lines (0, 36, 90, 144, 180, 216, 270, and 324 degrees) with numbered tic marks, allowing the subject to ensure that a balanced field-of-view is available. This is followed by a practice trial in which the subject is familiarized with the testing procedure. The trial also allows for verification of the centering of the subject's field-of-view.

The target stimulus consists of a small, high contrast, computer-generated tic mark which enters the subject's visual field along one of the eight different meridians, and progresses towards the center in increments of approximately 1/8th of a degree and at a rate of two incremental steps per second. The selected meridians are at the following angles: 0, 36, 90, 144, 180, 216, 270, and 324 degrees. A center reference cross and a short meridional indicator line are generated for each target. The purpose of the indicator line is to alert the subject to the entry direction of the target. Subjects are directed to look in the direction of the entering target. This approach determines the field over which information can be perceived (McLean and Rash, 1984; Walsh, Rash and Behar, 1987). This field is different from the static field, i.e., the measured field where the subject is directed to fixate on a center point and not permitted to move his eyes.

The test consists of four presentations along each meridian for each condition for each subject, first in a counterclockwise direction, and then in reverse direction for each successive presentation. The subject presses a hand-held switch upon each detection of the target. An audible beep is generated to provide positive feedback for each detection.

The procedure is repeated for a eye clearance distance of 10 mm greater than the user adjusted optimal eye clearance distance.

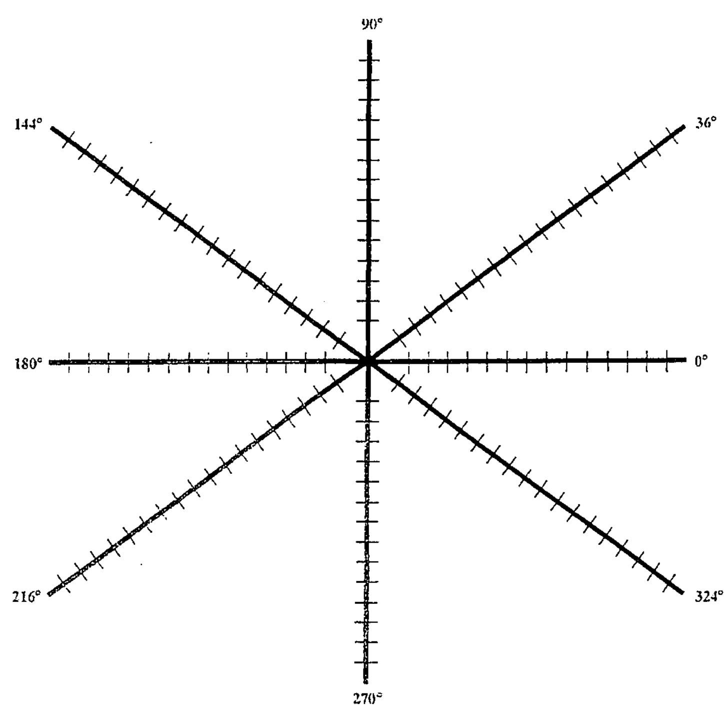


Figure 11. Pattern for image intensification field-of-view target board and CRT imagery field-of-view alignment.

Image intensification imagery: The target board is located at the required viewing distance from the I^2 tubes which the target board's markings to subtend angles equal to the design field-of-view values.

Following proper fitting, system alignment, and focusing using the manufacturer's recommended procedure, each subject will view the target board monocularly for each eye and report the available field-of-view to the nearest tic mark for each meridian.

The procedure is repeated for a eye clearance distance of 10 mm greater than the user adjusted optimal eye clearance distance.

3.1.3.2.1.5. Analytical method

For the I^2 field-of-view, the recorded values are converted to angular subtense using trigonometric conversions based on the viewing distance.

The individual monocular fields for each subject are plotted in the format of Appendix 4. To investigate the effect of display alignment along any given meridian, a secondary data analysis will be performed on pairs of collinear meridians, i.e., 0 and 180, 36 and 216, 90 and 270, and 144 and 324 degrees. For example, misalignment along the horizontal image axis could result in a measured field increase along the 0 degree meridian, but with a corresponding decrease along the collinear 180 degree meridian. This is compensated for by forming á collinear data value from the sum of the 0 and 180 degrees values.

The maximum vertical and horizontal monocular and overlap (for partial overlapping systems) fields are determined from the plots.

3.1.3.2.2. Display image overlap

3.1.3.2.2.1. Objective

To measure the size and shape of the right and left binocular overlapped field-of-view of the total display field-of-view.

3.1.3.2.2.2. Criteria

As required by specification documents.

3.1.3.2.2.3. Apparatus

Testing requires a viewing wall or screen located three meters or greater from the observer. Also required are an electronic test pattern with a bright background extending to the edge of the display (Figure 12) and a small, rod-mounted, high contrast target or moveable pointer.

Alternate apparatus and procedure shall have a minimum resolution of 0.5 degrees.

3.1.3.2.2.4. Procedure

The IHDS is mounted rigidly and adjusted for brightness such that the image from the IHDS and the see-through vision are comparable. To differentiate which image is seen by which eye, the observer may occlude an eye, one of the ocular channels, or turn one of the channels off.

The observer, viewing through the IHDS, directs an assistant to outline and mark the edges of the display in the overlapping region on the viewing wall or screen for each eye using either the high contrast target on a rod or the user moved projection pointer.

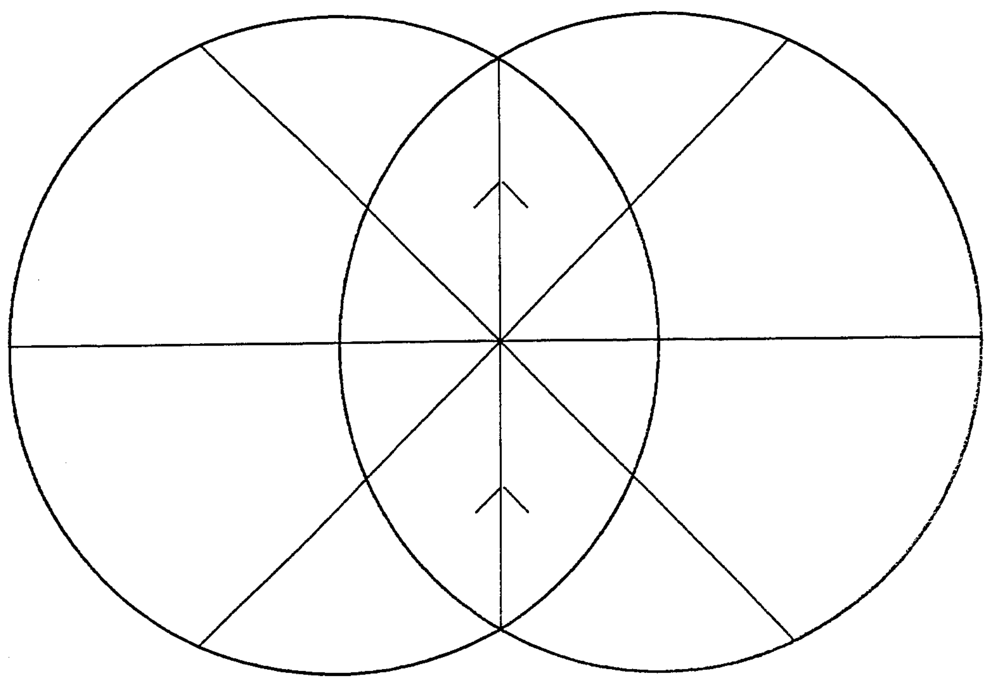


Figure 12. Display image overlap test pattern.

Three different observers with narrow, medium, and wide IPDs are tested. Suggested IPD values are 63-65 mm for medium, less than 60 mm for narrow, and greater than 68 mm for wide. If more than 2 degrees discrepancy is found in the designed and measured degrees of overlapping fields-of-view for the 3 subjects, at least 5 subjects shall be used for the particular IPD range with the discrepancy.

If IHDS has user adjustable overlap, the range of adjustment shall be measured.

3.1.3.2.2.5. Analytical method

Plots of the overlapped edges of the right and left displays as seen by the observer (ASBO) are made using the format in Appendix 4. The vertical and horizontal dimensions of the overlapped field-of-view are determined and compared with system specifications. These results also may be compared to the overlapped region determined in paragraph 3.1.3.2.1. (Display field-of-view).

3.1.3.2.3. Display resolution (Visual acuity)

3.1.3.2.3.1. Objectives

(1) To determine the minimum display luminance required to obtain the criteria resolution for a high contrast target.

(2) To determine the maximum IHDS subjective resolution with the minimum display luminance with no see-through background luminance (a) with the eye positioned on and off the designed line-of-sight, and (b) with central and peripheral target locations.

(3) To determine the minimum separable resolution of a high contrast video target when viewed against uniform backgrounds of 1, 10, and 100 fL.

(4) To determine the stroke written line widths (50 percent measured luminance point) and character dimensions for day and image overlaid symbology.

3.1.3.2.3.2. Criteria

(1) IHDS monocular vertical and horizontal resolution with a display background luminance of less than 10 fL shall be equal to or greater than 0.7 cycles/milliradian (20/50 Snellen equivalent) for high negative contrast targets in the center of the monocular field-of-view and better than 0.57 cycles/milliradian (20/60 Snellen equivalent) at 0.75 distances from the center to the edge of the field-of-view. With 3 mm of perpendicular displacement from the visual axes, the central and peripheral monocular resolutions shall be no worse than 0.57 cycles/milliradian (20/60 Snellen equivalent) and 0.5 cycles/milliradian (20/70 Snellen equivalent) respectively.

(2) A criterion for IHDS display resolution for a given background luminance has not been established.

(3) For day symbology, the line widths shall be approximately 1.0 ± 0.7 milliradians at image luminance settings appropriate for unaided viewing with background luminance range of 1 to 3000 fL. Noncautionary alphanumerics shall be 7.0 ± 2.0 milliradians (24 arcminutes) in height.

Where required, additional or alternate criteria from specifications documents shall be used for these tests.

3.1.3.2.3.3. Apparatus

A complete IHDS with display drive electronics is required. The electronic display drive unit shall be operated at the bandwidth and line rate of the intended input. A test pattern source capable of producing square wave bar targets shall be used. The background of the test pattern shall be light with dark bar targets (Figure 13). The spacing between the dark bars shall equal the width of the dark bars. The bars shall be orientated both vertically and horizontally. The height to width ratio of the bars shall be 5 to 1. The width of the bars shall be variable with a minimum bar width of ½ the width of a raster line increasing in size in increments of 1.12 (6th root of 2) or smaller. The source shall be capable of positioning the pattern at 5 locations: the center, and 75 percent of the distance from the center to each monocular horizontal and vertical edge of the display.

A digital high resolution scanned video system may be used to produce the 3-bar resolution charts for the IHDS test pattern. The resolution of the scanner must be at least twice the number of video lines used by the IHDS. The resolution chart then is transferred to the IHDS and displayed using the intended line rate and video bandwidth. Initial performance and size calibration for the chart can be determined using a high resolution monitor.

Recommended for the subjective high contrast resolution assessment for unaided vision and through the IHDS is the Air Force 3-bar chart (Figure 14) or equivalent. Hard copy resolution targets shall be scanned and stored at resolutions at least twice the IHDS maximum line rate.

Additional equipment required includes: photometer, diopterscope, target telescope, and diffused light source to produce a variable intensity uniform viewing background of at least 40 degrees minimum dimension and at luminance levels up to 100 footlamberts (fL).

3.1.3.2.3.4. Procedure

Testing of IHDS minimum separable resolution shall be a subjective assessment, based on five or more trained observers correctly identifying the orientation of different sized 3-bar targets. Since the limiting resolution measurement is subjective, selection and training of observers is required.

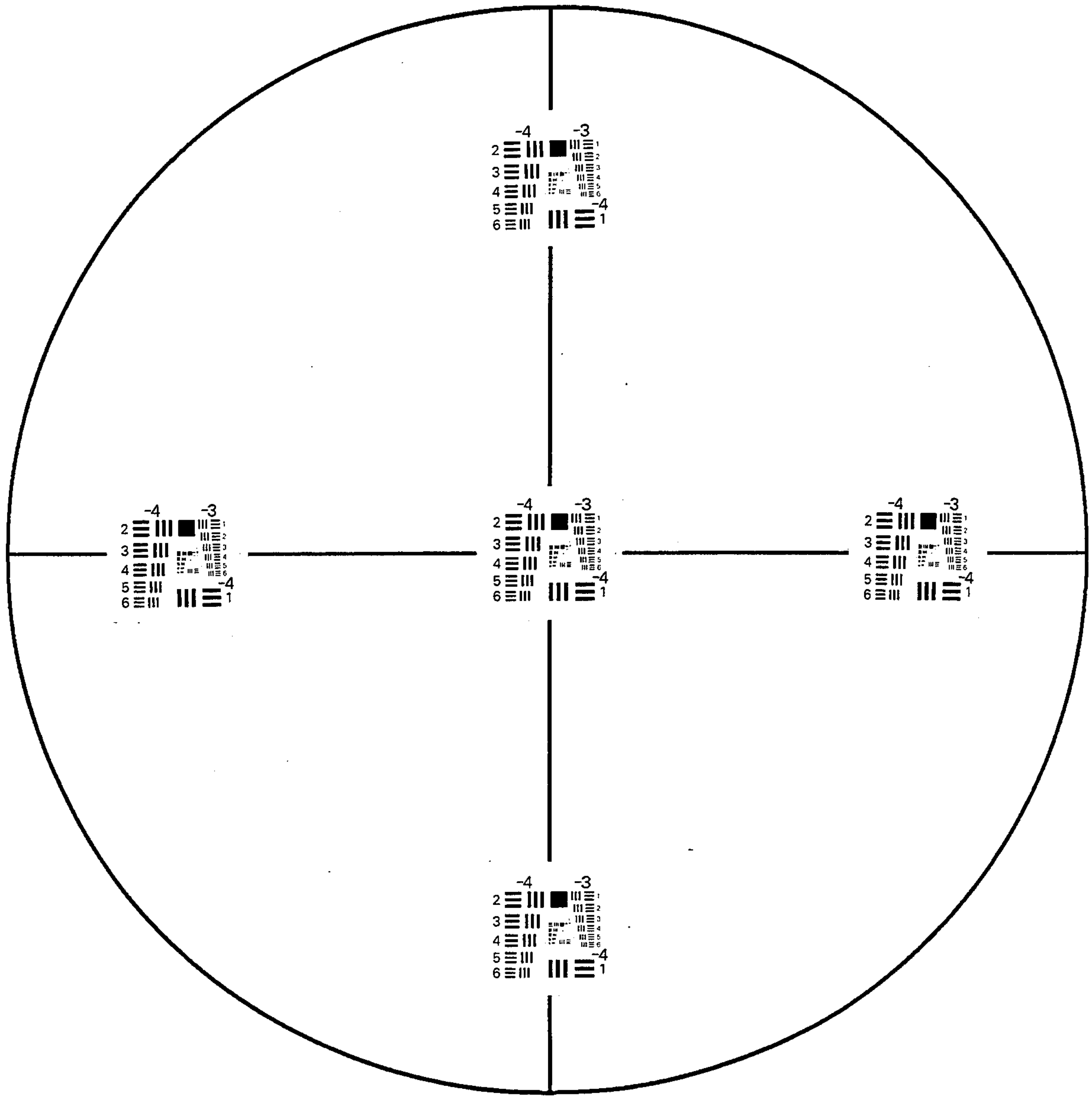


Figure 13. Display resolution test pattern.

<u>Subjects</u>: The subjects to be evaluated for selection as trained observers for visual acuity measurements shall be aviators between ages 20 and 40 and shall have a current Class II flight physical or equivalent. Corrective lenses are permitted.

The subjects will be briefed on the design of the resolution chart and the desired criteria for reporting limiting resolution (i.e., the two spaces between the three black bars are just visible). The subjects shall have practice sessions using unaided vision with a hard copy of the same 3-bar high contrast resolution chart that shall be used for the test chart as seen trough the IHDS. The luminance on the chart shall be varied from scotopic to low photopic levels. The light source for the hard copy

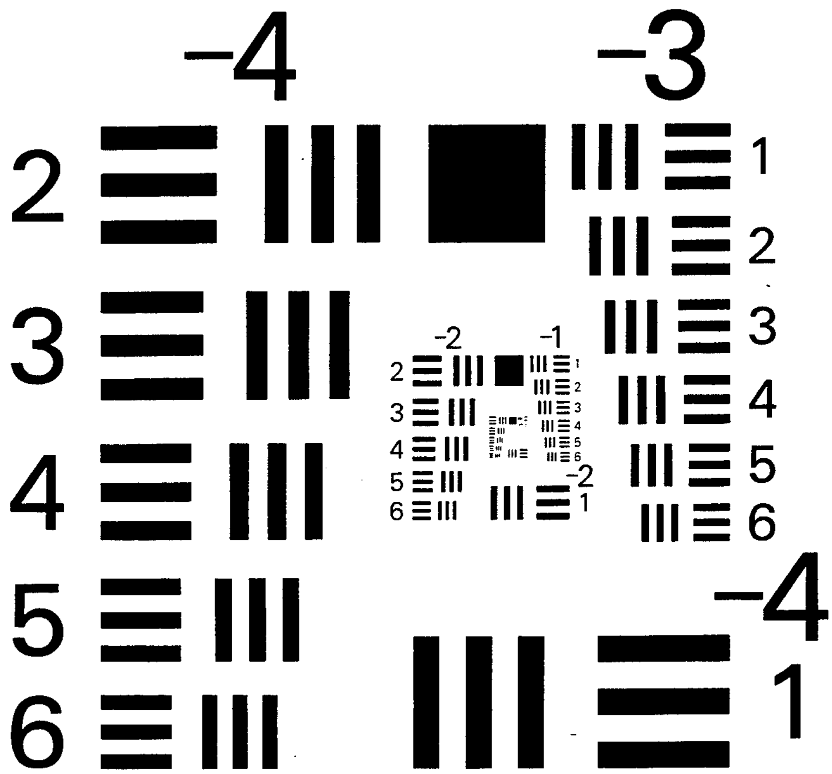


Figure 14. U.S. Air Force 3-bar resolution chart.

resolution chart shall have adequate range of luminous flux to provide scotopic to low photopic vision without changing color temperature significantly with changes in luminance. The viewing distance shall be six meters and the resolution measured monocularly. During the practice sessions, if the subject reports more than one element difference (1.12 to 1 in target size) between the resolution of the vertical and horizontal bar targets at any given luminance level, the subject shall not be selected as an observer for the IHDS resolution test.

After adequate practice where a subject has demonstrated repeatable resolution criteria for a given background luminance, baseline data of resolution versus background luminance shall be determined. Subjects are dark adapted for at least 15 minutes and one eye is patched. The target luminance is slowly increased by the experimenter and the background luminance recorded with a photometer that corresponds to a given resolution between 20/200 and 20/25 Snellen equivalent. Five data points are taken for 5 resolution values or more between approximately 20/200 and 20/25 Snellen equivalent. The resolution values are not randomized, but given serially, beginning with the larger sizes and lowest light levels and progressing to the smaller sized targets and higher light levels. The selected resolution values shall be proportionally spaced. Conversions of the

group/element identifiers of the Air Force 3-bar chart to the Snellen equivalent (English and metric) for the suggested resolution values at 6 meters are presented in Table 2.

Table 2.

Air Force 3-bar to Snellen resolution conversions

AF 3-bar chart group, element	Snellen resolution - English (metric)
-6,6	20/206 (6/62)
-5,5	20/116 (6/35)
-4,3	20/73 (6/22)
-3,2	20/41 (6/12)
-3,6	20/26 (6/8)

After baseline data are determined for a minimum of five subjects, the means and standard deviations of the background luminance in log units needed to obtain the selected resolutions for vertical and horizontal lines are calculated for each subject and as a group. For the resolution values between 20/40 and 20/120, any subjects having background luminance values beyond 2 standard deviations, plus or minus, from the average of the group shall not be selected as a trained observer for the resolution measurements through the IHDS.

IHDS limiting resolution assessment: Testing is conducted monocularly. Resolution/ luminance measurements are recorded for the following conditions, but not all combinations: (1) minimum background luminance to obtain minimum resolution criteria at the center of each display (contrast controls set at maximum); (2) minimum background luminance to obtain the maximum resolution at the center of the display (contrast controls set a maximum); (3) same as #2, but contrast and brightness controls adjustable by observer; (4) eye positioned at designed line-of-sight; (5) the eye displaced ±3 mm vertically and horizontally off the designed line-of-sight; (6) the resolution targets positioned on the vertical and horizontal meridians approximately 75 percent of the distance from the center to the edges of the displays; and (7) maximum central resolution with background luminances of 1, 10, and 100 fL.

The IHDS is adjusted/fitted initially by or for each observer for proper alignment and focus according to the contractor's instructions using a suitable test pattern. The evaluator shall measure the diopter settings and any mechanical adjustment positions used by each observer.

In the first part of the test, the minimum separable resolution of a high contrast video target in the center of the monocular field-of-view is determined monocularly against a blank, dark background. With the observer adapted to a very dark background for at least 15 minutes, the display contrast control(s) are set in the maximum position and the brightness control(s) in the

minimum position. The display is increased slowly in brightness by the observer until the display resolution criteria are obtained for both horizontal and vertical bars with the minimum luminance. The subject shall be allowed to oscillate the brightness control at least three times to determine this minimum luminance value. The display background luminance is measured with a photometer, and the vertical and horizontal resolutions recorded.

The observer continues to increase the brightness until no further improvement is noted in resolution. The observer is allowed to oscillate the brightness control at least three times to determine this minimum luminance value for maximum resolution. The display background luminance is measured with a photometer and the "best" resolution for both vertical and horizontal bars recorded.

The procedure is repeated again allowing the subject to alternate between brightness and contrast control adjustments until maximum central resolution is obtained with the minimally perceived background luminance. Note: This procedure would theoretically not be required for a high contrast target if the brightness and contrast controls were totally electronically independent of each other, but this is usually not the case. The luminance of the background ASBO is measured with a photometer and the resolution recorded. The procedure is repeated for the other ocular channel.

After both right and left ocular channels have been optimized for maximum central resolution with the minimum background luminance, the brightness and contrast controls are fixed at these positions for the off-axes evaluations. The subject then looks monocularly at each of the 4 targets located 75 percent of the distance from the center to the edge of the field-of-view and determines the location and resolution of the best and worst targets (horizontal and vertical bars evaluated separately) in each channel.

Without changing any of the display controls, the exit pupils are moved laterally by 3 mm. This may be accomplished by increasing and decreasing the IPD by 6 mm. Central and best/worst peripheral target acuities for horizontal and vertical bars are recorded monocularly for both temporal and nasal displacement of the exit pupils. The IPD then is readjusted for the proper IPD and the displays are displaced first up and then down vertically by 3 mm. Resolutions are recorded monocularly for both up and down displacements for central and best/worst peripheral target acuities (vertical and horizontal bars).

The subjective maximum monocular resolution measurements at the designated line-of-sight for a central target are repeated using real backgrounds with luminances of 1, 10, and 100 footlamberts, plus 10 percent. The viewing backgrounds may be located at any distance, but they shall be relatively uniform. The minimum dimension of the background field-of-view shall be 40 degrees or greater. Observers are allowed to adjust brightness and contrast controls. All intervening optical media that normally would be used for night flight shall be included (combiners and clear visor).

Symbology line width: Procedures for measuring the line widths and alphanumeric character dimensions of the day and image overlaid symbology may include the instrumentation used for measuring the modulation transfer function (MTF). The line width shall be defined as the 50 percent luminance point. The luminance of the day symbology shall be adjusted to a contrast ratio (CR) of 7:1 or less ASBO for the 1 fL background and greater than 1.5:1 contrast for the 3000 fL background.

If subjective methods are used to measure symbology line widths and alphanumeric character dimensions, a telescope with magnification greater than 5X and test charts with approximately 0.2 milliradian calibration accuracy shall be located a minimum of 20 meters away either optically or actually. The 1 fL background can be produced in the laboratory, but the approximately 3000 fL background with 40 degrees or more angular subtend is easier to obtain with a real sky horizon and/or a white target board against the sky horizon. The visible line widths of the symbology are measured with either internal reticle calibration marks in the telescope or a white target board with calibration markings.

3.1.3.2.3.5. Analytical method

(1) For the subjective measurement of the minimum display luminance to obtain the criteria resolution, the means and standard error of the logarithm of the measured right and left channels for all observers shall be calculated and compared to the minimum logarithm of the background luminance criteria (10 fL) for centrally located targets. Only one background luminance value is measured for each observer.

(2) The mean and standard deviation of the minimum display luminance for the maximum vertical and horizontal resolutions shall be calculated to fully characterize the display, to include whether contrast and brightness controls were needed to optimize resolution. Only one luminance reading is measured for each subject for each testing condition.

(3) The means and standard error of the resolutions, expressed in cycles/milliradian, for visual axes displacements and peripheral targets shall be calculated and compared to the display specifications.

(4) The means and standard error of the resolution for central vertical and horizontal targets when viewed against background luminances of 1, 10, and 100 fL shall be calculated and compared to display specifications.

(5) The symbology line widths and alphanumeric character dimensions shall be compared to display specifications.

3.1.3.2.4. Display extraneous images

3.1.3.2.4.1. Objective

(1) To determine the generating location and intensity of ghost (reflective) images from external light sources when using the IHDS.

(2) To determine the presence and relative luminance of multiple images from the internal imaging source.

(3) To determine the contrast reduction of day symbology when IHDS is operated in high ambient illumination with tinted visor.

3.1.3.2.4.2. Criteria

Criteria for extraneous reflections with a day and night IHDS have not been well quantified or previously defined. Any visible reflected images ASBO from internal or external sources will degrade IHDS or see-through image quality, and these ghost images cannot be eliminated totally with any known IHDS systems that use combiners. These reflections may be only a minor temporary nuisance for a given condition and viewing angle, or render the IHDS useless and create a grave safety concern.

A thorough review of potential ghost images from external light sources to include the range of locations and intensities shall be conducted for the intended use of the IHDS. Sources to be included in this list would be the sun, aircraft cockpit lighting, and head down displays.

Some previous values suggested for ghost images have been 5 percent or less. Normally this would be an acceptable value if the reflections are internally generated or are from the instrument lights. However, if the sun is the reflected source, with a 5 percent reflectance, the reflected intensity ASBO would be approximately 250,000 fL (assuming a sun luminance of approximately 5 million fL). The apparent size of the reflected sun image shall depend on the curvatures of the surfaces responsible for the ghost image.

Based on the previous discussion, criteria are stated as follows:

(1) Display extraneous images shall not induce a safety hazard under any circumstance or significantly degrade performance except under infrequent circumstances, conditions, or situations.

(2) Symbology- For evaluating secondary reflections when using symbology: If the minimum visible symbology in the white portion of the see-through background field-of-view shows a secondary image in the darker field-of-view (10 percent of white), then the IHDS fails the ghost image requirement.

(3) An acceptable value for induced glare (or the ratio of glare luminance to ambient illumination) in an outside environment for an IHDS has not been established.

Where required, additional or alternate criteria from specifications documents shall be used for this test.

3.1.3.2.4.3. Apparatus

Laboratory: Equipment includes: A pen light and light pointer; a diffused hand held luminance source of 500 fL or greater subtending between 1 to 3 degrees ASBO; angle measurers--gravity type and protractor, and/or suitable distant measuring devices; photometer; observing background with the lower field-of-view painted in a dark grey and the upper field-of-view painted white (the contrast ratio between the dark and white viewing area shall be approximately 10:1). The white and dark grey portions of the target shall subtend at least 5 degrees vertically and horizontally. The IHDS shall be rigidly mounted such that observer can use the IHDS, but the IHDS cannot move.

Field: A black and white target -- white on top, and black on bottom and joined with a 90 degree angle. The top white target is tilted back at 45 degrees from the vertical, which also tilts the bottom of the black target 45 degrees backwards (Figure 15).

3.1.3.2.4.4. Procedure

(1) Laboratory light source method: An experienced observer is seated in a dark room wearing the IHDS. The IHDS is turned off. The observer and/or experimenter moves the pen light throughout 270 degrees in azimuth (centered at the design line-of-sight) and within the useable range of elevations (approximately 70 degrees down and 90 degrees up). The source light is moved in approximately 15 degree increments in elevation and rotated about the observer. The observer indicates to an assistant with a separate pen light or light pointer when and where reflective images are seen. The source pen light can be mounted on a string of known length (approximately 1 meter), and the vertical and horizontal angles are measured. When a reflection is observed by the observer, the experimenter would move the light source in smaller angular increments to determine the shape and boundaries of the reflecting area. At a given location of a reflection, the observer will rate the apparent intensity of the reflection on a ranking type scale (no upper or lower limits).

The locations of the light source and any residual reflections are plotted using a polar coordinate system, sequentially numbering and pairing the source and reflections, and using a color code to differentiate between the source and the reflection. The apparent intensity ranking by the observer is recorded by reflective location on a separate coordinate form.

The luminance of a small sample of the reflections are measured using the photometer and the calibrated diffuse light source after the angular locations of the light and reflective images are mapped. Performing the measurements may be difficult due to photometer alignment with the reflected image for an IHDS that includes the helmet.

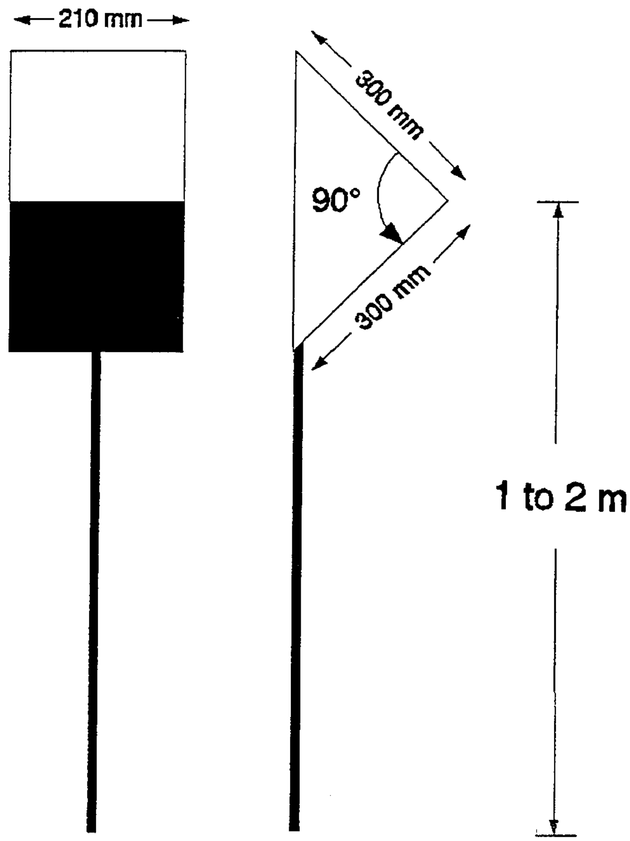


Figure 15. Black and white target for field evaluation of display extraneous images.

(2) Symbology/imagery method:

Symbology: Secondary reflections originating in the image generation of the IHDS may be detected by using the symbology only (probably stroke written) while observing in a dark room. The intensity of the symbology is increased gradually to the maximum value and the observer looks for the presence of secondary reflections (duplicate images).

If secondary reflections are detected, the technical observer views the bisected light and dark background with the background luminance of the white portion illuminated between 100 to 500 fL. The observer adjusts the symbology until it is barely visible for symbol characters and legible for alphanumeric characters against the white background. The observer then tilts his head (and IHDS) downward to position the symbology to be viewed with the dark grey background. Observer indicates the presence or absence of secondary reflections.

Imagery: In a dark room, a greyscale test pattern is displayed on the IHDS. The greyscale test pattern shall be generated containing 16 square-root-of-two shades of grey. The 16 shades shall be located in the center of the display and at approximately 3/4 of the distance to the edge of the display. Each shade shall have a horizontal and vertical dimension of approximately two percent of the horizontal and vertical display dimensions (Figure 16). With the contrast control set for maximum, the brightness control gradually is increased as the observer looks for secondary reflections or secondary images of the display. When internal reflections are observed, the number of visible greyshades are counted and the luminance of the white greyshade measured with a photometer.

(3) Field method: The procedure to determine the contrast reduction of symbology in high ambient illumination is conducted outside in an open area. The sun shall be between 30 and 60 degrees in elevation and not obscured by clouds or excessive haze. The IHDS is not activated. The target and IHDS are positioned at 3 different angles with respect to the sun: (1) directly in front of, (2) directly behind, and (3) to the side of. The black and white target is mounted at a height of 1 to 2 meters above the ground. The reflectance of the ground beneath the target should be approximately uniform for a minimum radial distance of 3 meters.

The IHDS is mounted rigidly approximately 3 to 6 meters from the black and white target, at the same height, in an "as worn" position, and with tinted visor. The objective lens of the photometer is positioned at the right or left design eye location and aligned with the black and white target (Figure 17). Measurements of the white and black components (L_{wm} and L_{bm}, respectively) of the target are taken with and without the IHDS in place. Approximately 5 measurements shall be made for each condition. Illuminance measurements also are recorded for documentation. Measurements are repeated for the other eye and at the 2 other orientations with the sun. The added stray light is related to the 4 luminance readings for a given sun position by the following equations:

$$L_{wm} = (L_w \times T) + G$$

and

$$L_{bm} = (L_b \times T) + G$$

where T = Percent luminance transmission through IHDS combiners and tinted visor
and G = Luminance (fL) from glare, reflectance, optical media haze, etc.

The constants T and G are fixed for a given sun relationship and visor configuration. Since L_w, L_{wm}, L_b, and L_{bm} are measured values, the above equations can be solved for the glare component, expressed as:

$$G = L_{wm} - [(L_w)(L_{wm} - L_{bm})/(L_w - L_b)]$$

or

$$G = L_{bm} - [(L_b)(L_{wm} - L_{bm})/(L_w - L_b)]$$

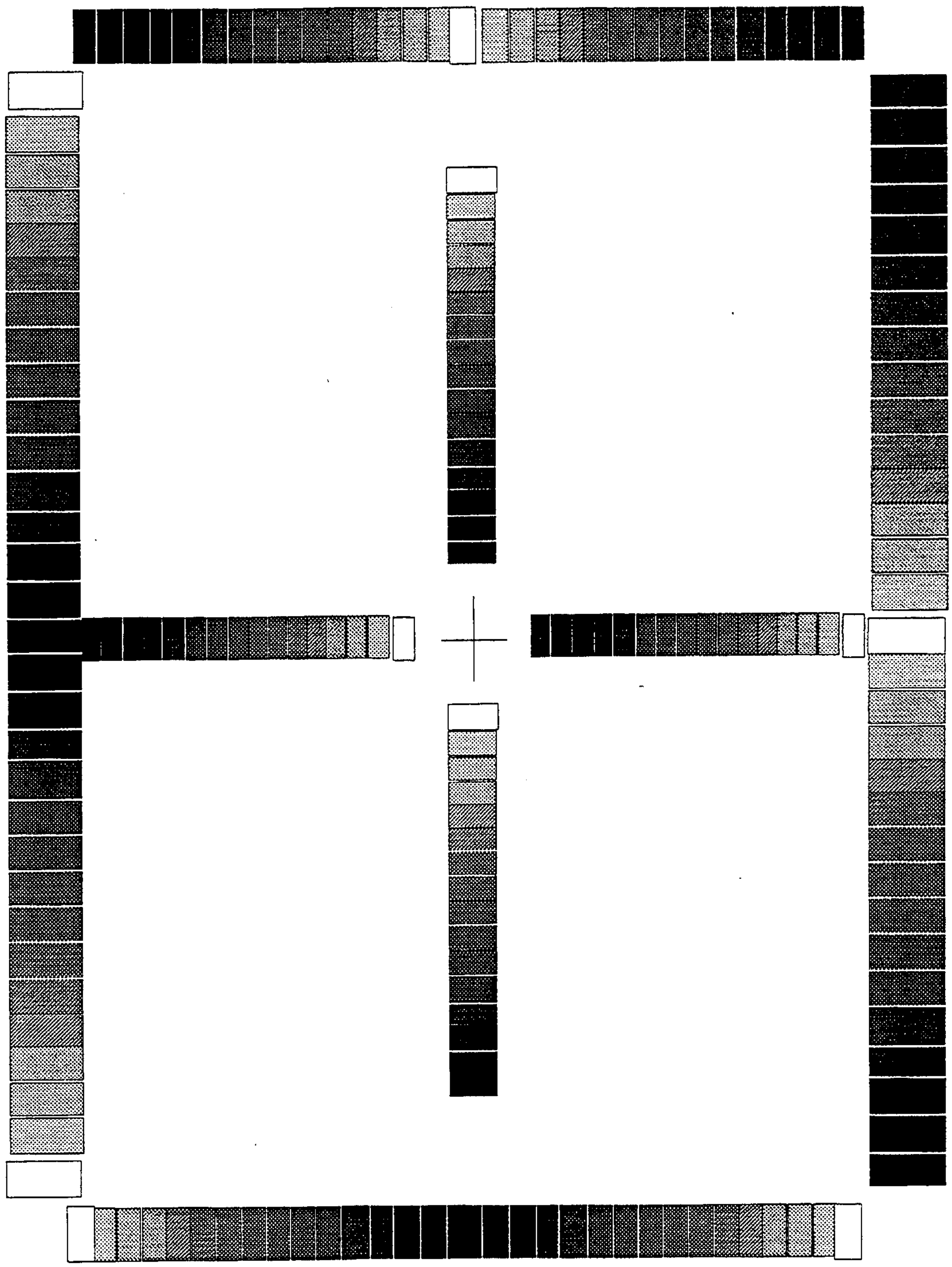


Figure 16. Greyscale test pattern.

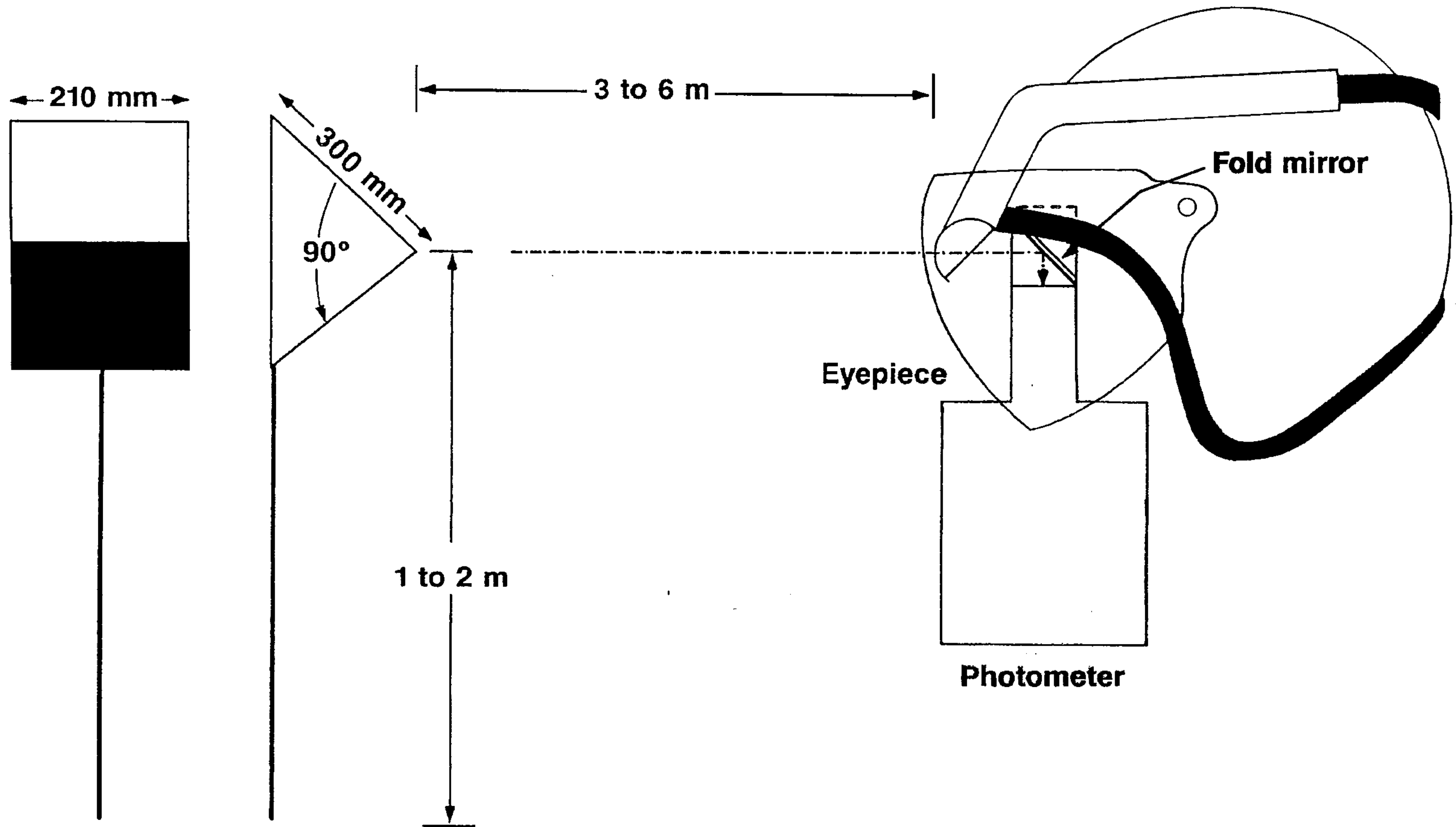


Figure 17. Experimental setup for extraneous images, imagery field method.

The glare luminance to ambient illumination would be calculated as the ratio:

G/IL

where G is expressed in fL and IL (ambient illumination) is expressed in footcandles (fc).

3.1.3.2.4.5. Analytical method

(1) The locations of both the luminance source and its corresponding reflective image shall be plotted using polar coordinates.

If measurable, the percent reflectance will be calculated from measurements of the luminance of the source and the reflected ghost image.

(2) Symbology: If the subjective method is used to evaluate symbology viewed against a bisected dark and light background, a pass or fail is recorded by the observer. Additional comments may be desired if some symbology passes and others fail, such as the location in the field-of-view and size characteristics.

Raster: No secondary images or ghosts shall be visible throughout the image brightness range for raster imagery. However, if they are detected, the measured upper luminance value shall be considered the maximum useable luminance range for calculating display contrast ratio for a given background luminance.

(3) The mean glare (G) value for the right and left channel shall be calculated for each sun angle condition and expressed as a percent of the illumination.

3.1.3.2.5. Display luminance range

3.1.3.2.5.1. Objective

(1) To determine the user adjustable raster and stroke luminance range for CRT imagery; to determine the ratio of output luminance to input luminance (brightness gain) for helmet-mounted image intensification systems.

(2) To determine if the adjustable range of the day symbology is adequate for legibility of stroke symbology when viewing against a bright sky horizon (3000 fL).

3.1.3.2.5.2. Criteria

(1) The luminance range of raster or image intensification imagery shall be sufficient to conduct nap-of-the-earth (NOE) pilotage in all light levels below that required for unaided vision in see-through configurations. A lower adjustable luminance value for a high positive contrast target

is 2 fL or less. An adequate maximum adjustable display value depends on the see-through transmission of the IHDS design. MIL-A-49425 requires the brightness gain ASBO not to be less than 2000.

(2) Stroke symbology shall be visible and legible against a background luminance of 3000 footlamberts (fL), i.e., ambient illumination of 9300 footcandles (fc), approximately 100,000 lux. A tinted visor is permitted. Recommended minimum contrast ratio defined as [(symbology + background)/background] is 1.5.

Where required, additional or alternate criteria from specifications documents shall be used for this test.

3.1.3.2.5.3. Apparatus

Raster imagery measurement: A photometer (as defined in paragraph 3.1.3.1.5.3.), calibrated with an objective lens aperture smaller than test device's exit pupil, and with a viewing aperture smaller than image line width, is required. An electronically generated raster test pattern, consisting of white squares on black background in a 3 X 3 design (with the center square being white), shall be used (Figure 18). The white squares shall be located in the center of the display and on the 8 primary meridians, approximately 75 percent from the edge of the display. The squares shall be a minimum of 2 degrees and a maximum of 5 degrees in width. The pattern in Figure 18 would be used for a monocular or fully overlapped biocular/binocular system. For a partially overlapped system, a pattern as in Figure 19 would be used.

Image intensification measurement: Brightness gain is measured using a variable radiance 2856°K light source (with wide angle, uniform field collimator or integrating sphere) and a photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less, and photopic and scotopic filters. Approximately a 7 mm diameter aperture is placed in front of the objective lens of the photometer and a conversion factor determined to calibrate for absolute luminance measurements. Note that the entrance pupil of the photometer must be smaller than the IHDS exit pupil diameter.

Stroke imagery measurement: The stroke character generator with typical daytime flight symbology will be used. Also, required are neutral density filters in 0.1 log increments.

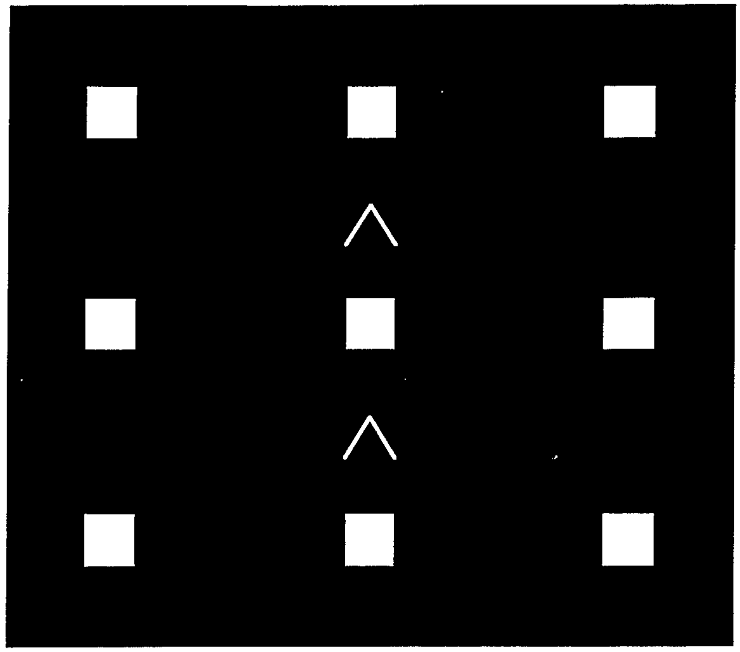


Figure 18. Black and white square test pattern for evaluation of display luminance in monocular/fully overlapped biocular/binocular systems.

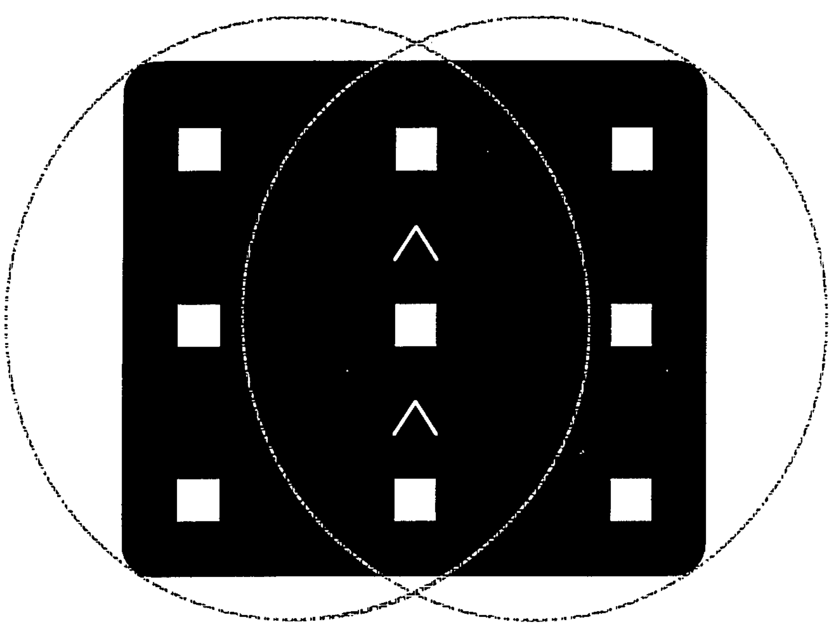


Figure 19. Black and white square test pattern for evaluation of display luminance in partially overlapped biocular/binocular systems.

3.1.3.2.5.4. Procedure

Raster imagery measurement: The user's contrast control is set at maximum. In a dark room, the test pattern is increased in luminance using the brightness control until the dark test pattern background is just perceivable as increasing in luminance. The observer is instructed to adjust the brightness control in both directions until he is satisfied.

With the objective lens aperture of the photometer placed at or behind the test device exit pupil, the luminance of each square (nine total), and the adjacent background, is recorded. The photometer may have to be moved laterally and vertically until the maximum reading is recorded for each square.

With the photometer pointing at the adjacent background for the center square, the luminance for the background is increased by a factor of approximately two over the initial luminance of the background. The resulting luminance of the center square is measured and recorded. This procedure is continued (increasing the background luminance) until there is no measurable increase in the luminance of the square or the brightness control has reached its maximum value.

Image intensification measurement: The procedure for measurement of luminance (brightness) gain was developed at the Armstrong Aerospace Medical Research Laboratory, Wright-Patterson Air Force Base, Ohio (Task, Hartman, and Zobel, 1991). Following calibration of the light source, the I^2 device is placed as close to the light source as possible. The aperture of the photometer is placed at the design eye (or exit pupil) position and aligned with the center of the I^2 field-of-view. The measuring aperture of the photometer shall be no less than 20 arc minutes.

The light source is adjusted to provide an input luminance of 0.00001 fL. The output luminance of the I^2 device is measured with the photometer and recorded. The output of the source is then doubled and the I^2 output measured and recorded. These steps are repeated up to a source setting of approximately 0.02 fL.

Stroke imagery measurement: (Objective method) In a dark room, the flight symbology is adjusted for maximum luminance. Using a photometer with the acceptance aperture smaller than a line width of the smallest alphanumeric characters, the luminance of a central character or symbol is measured and recorded. This measurement is repeated for each type of symbology. If the minimum luminance of the symbology cannot be adjusted by the user to a zero value, the minimum adjustable luminance shall be measured using a central symbol.

(Subjective method) This method can be used only if a plot of the luminance values of the image generating device (e.g., CRT) versus the control input position is known or has been measured previously through the IHDS and is consistently repeatable.

If the luminance measurements are conducted in a laboratory, the viewing background shall approximate the same spectral distribution as the sky slightly above the midday horizon. The

viewing background shall have a luminance value between 2000 and 4000 footlamberts and subtend a diameter of 40 degrees or more. Initially using the clear visor, the luminance of the symbology is increased until any symbol is visible. (Note: For symbology for a particular IHDS design, the display luminance may be in discrete steps and not analog.) If analog, the position of the brightness control is calculated as the percent of maximum angular range. For example, if the stroke brightness control can be rotated 180 degrees, and a symbol is minimally visible with the control positioned at 90 degrees, the recorded value would be 50 percent. This brightness control setting is measured and recorded for each type symbology. This measurement also is performed for alphanumeric characters, where the brightness control is increased until the characters are just legible.

Even at the maximum luminance setting, all of the symbology and alphanumerics may not be visible or legible with just the clear visor with a background of 2000-4000 footlamberts. If this is the case, the tinted visor is used and the above procedure repeated.

The above procedure is repeated for any other visor or media protective device not meeting the chromaticity neutrality requirements.

3.1.3.2.5.5. Analytical method

Measured luminance values shall be compared to test criteria. For the I^2 measurement, luminance gain is calculated by dividing the output luminance by the input luminance. Gain values are presented graphically as a function of input luminance.

3.1.3.2.6. Display grey levels

3.1.3.2.6.1. Objective

To determine the number of greyshades (square-root-of-two intervals), the IHDS can present against a scotopic and a low photopic background.

3.1.3.2.6.2. Criteria

With the clear visor, the number of visible square-root-of-two greyshades for display imagery shall be equal to the number of greyshades produced by the sensor, or greater than 10, whichever is less, when the background luminance ASBO is 0.1 fL. The ratio of the luminance values for the adjacent grey levels shall be between 1.55:1 and 1.27:1, excluding the brightest and darkest levels. If the luminance outputs from the display are in discrete steps, as found in a digital display system, the luminance differences between grey levels (or steps) shall be logarithmic and the number of available steps (or luminance levels) shall be a minimum of 16. There is no greyshade requirement for day symbology, but the contrast ratio requirement must be met (subsection (2) of paragraph 3.1.3.2.5.2.).

Where required, additional or alternate criteria from specifications documents shall be used.

3.1.3.2.6.3. Apparatus

A test pattern generator capable of providing greyscale test patterns with square-root-of-two luminance intervals between adjacent steps is required. A photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less, and photopic and scotopic filters is also required. In addition, a uniform light source with a capability of providing observing field luminances between 1×10^{-5} and 5 fL also shall be used.

3.1.3.2.6.4. Procedure

An electronic greyscale test pattern shall be generated containing 16 square-root-of-two shades of grey. The 16 shades shall be located in the center of the display and at approximately 3/4 of the distance to the edge of the display. Each shade shall have a horizontal and vertical dimension of approximately 2 percent of the horizontal and vertical display dimensions (Figure 16).

Scotopic background - The test pattern is generated on the IHDS, and adjusted for maximum number of visible contrast levels using a dark background for see-through vision. The grey levels shall be optimized using the greyshades located in the center of the field-of-view. The contrast and brightness user controls shall be adjusted such that the maximum number of grey levels are seen first with the dark side optimized and then with the light side optimized. This is required because the light grey levels may saturate in the first case, and the dark levels may be indistinguishable in the second case. The number of visible grey levels are counted in both cases and recorded. Any difference in the number of greyshades for the patterns located 3/4 the distance to the edges shall be recorded. The luminances ASBO of the central greyscale steps are measured with a photometer.

Low photopic background - The background luminance for the greyscale, using see-through vision, is adjusted to approximately 0.1 fL ASBO. The field-of-view for the observed background shall be a minimum of 40 degrees at its narrowest dimension. The observer readjusts the brightness and contrast controls of the IHDS to optimize the number of visible grey levels. The number of visible grey levels is reported by the observer. The display may be optimized first for the light and then the dark side of the greyscale if all the grey levels can not be seen at one control setting. The number of visible grey levels are counted in both cases and recorded. The luminance of the greyscales shall be measured with a photometer ASBO for each eye.

3.1.3.2.6.5. Analytical method

The measured luminances of the central greyscales are plotted versus the desired grey level for both the scotopic and low photopic backgrounds. The ratios of the adjacent grey levels are calculated and compared to systems specifications. Note: The number of reported possible "visible" greyshades could be greater since the observer may adjust contrast with less than a square-root-of-two difference between the adjacent shades.

Based on the usable contrast ratio from the measured greyscales, the number of possible square-root-of-two grey levels is calculated for the required background luminance (0.1 fL) in the system specifications.

3.1.3.2.7. Display image luminance disparity

3.1.3.2.7.1. Objective

To determine the difference in luminance between the right and left IHDS channels (if system is biocular or binocular) at low, medium, and high luminance settings. If the IHDS is biocular, only one luminance setting is required. Note: This test is not required if the brightness of each channel can be independently adjusted by the user.

3.1.3.2.7.2. Criteria

Central field luminance values for left and right channels shall differ by no more than 30 percent (0.15 log units) at low, medium, and high mean luminance values of presented imagery. Suggested display values for measurements are 0.1, 1.0, and 10 fL. For an integrated helmet-mounted I^2 device, the upper luminance value of the display shall be at the threshold of the automatic gain control.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.7.3. Apparatus

A photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less, and photopic and scotopic filters and an electronically generated negative contrast cross-hair using raster imagery are required.

3.1.3.2.7.4. Procedure

Measurements are made in a dark room with the photometer focused on the exit pupils of the IHDS along the optical axes. The display contrast in each channel is maximized. The IHDS display brightness is adjusted to the medium luminance level (1.0 fL) in one channel. The luminance of the alternate channel is measured and recorded. This procedure is repeated for the low (0.1 fL) and high (10 fL) luminance conditions.

3.1.3.2.7.5. Analytical method

The luminance differences between the right and left channels are calculated and compared with system specifications for the three luminance conditions using the following equation:

$$\% \text{ disparity} = 1 - (L_l/L_h)$$

Where L_l = luminance of the channel with the lowest luminance value

and

L_h = luminance of the channel with the highest luminance value.

3.1.3.2.8. Display chromatic aberration

3.1.3.2.8.1. Objective

To determine the presence of residual chromatic aberration in the IHDS.

3.1.3.2.8.2. Criteria

No chromatic aberration shall be visible for up to 4 mm of eye displacement perpendicular to the designated line-of-sight and within 15 degrees of the center of the field-of-view at an upper display brightness level appropriate for night pilotage tasks (10 fL recommended). No chromatic aberrations shall be visible within the IHDS field-of-view at normal display brightness level appropriate for night pilotage tasks (2 fL recommended).

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.8.3. Apparatus

A test pattern generator capable of providing either full-raster dot or grid patterns shall be used (Figure 20). The width of the grid lines or the diameter of the dots shall be between 0.50 and 0.05 degrees. The distance between dots/lines shall be approximately 5 degrees. The dots/lines shall have positive contrast (brighter than background) and the background shall not be visible. Reference lines or marks may be used on the test pattern or the see-through background to locate positions in the field-of-view.

3.1.3.2.8.4. Procedure

Testing is conducted in a dark room. The observer(s) shall have normal color vision and be dark adapted for at least 10 minutes. The brightness of the IHDS is increased gradually with the contrast setting in the maximum position. Observer looks monocularly at the edges of the test pattern (dots) for evidence of chromatic aberration (rainbows) at various parts of the field-of-view as the display brightness is gradually increased to the maximum useable level.

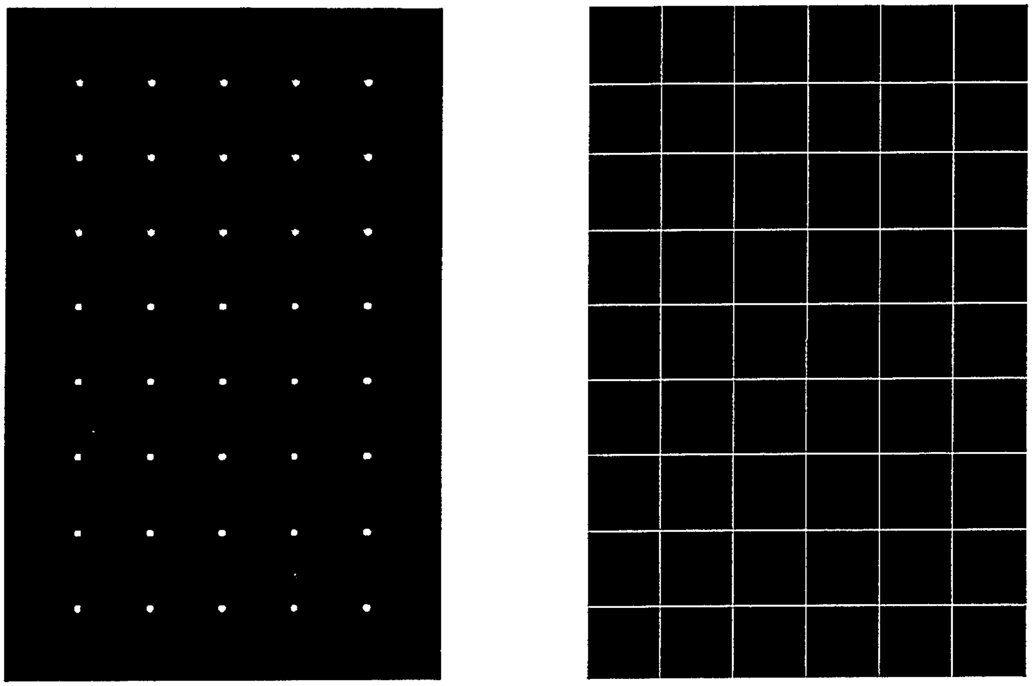


Figure 20. Full-raster dot and grid patterns.

If chromatic aberration is present within the central 15 degrees for a given luminance setting, the observer shall check for proper IHDS focus and alignment. If the chromatic aberration persists, the luminance of the display is decreased slowly until the chromatic aberration is not visible. The white portions of the test pattern ASBO are measured with a photometer and their locations recorded as to their angular position within the central 15 degree field-of-view around the designed line-of-sight. If the luminance values are less than twice the luminance criteria for visible chromatic aberrations, the procedure and luminance measurements are taken 5 times using a minimum of three trained observers.

Chromatic aberration is evaluated for the IHDS field-of-view outside 15 degrees from the central line-of-sight with the same procedure.

The procedure is repeated with the eyes displaced 4 mm from the designed line-of-sight in 2 opposite directions. Inter-pupillary adjustment may be used to produce the displacement.

3.1.3.2.8.5. Analytical method

If required from the initial photometer readings, the five measured luminance samples for each observer are averaged and compared to the system specifications for central and peripheral portions of the field-of-view. Eighty percent of the observers shall see no chromatic aberration below the specified luminance values.

3.1.3.2.9. Display contrast ratio

3.1.3.2.9.1. Objective

To determine the maximum and minimum adjustable contrast ratios for stroke symbology and raster imagery for see-through background luminances of 0, 1, 10, 100, 1000, and 3000 fL.

3.1.3.2.9.2. Criteria

Day symbology: The contrast ratio shall be adjustable and equal to or exceed a value of 1.5:1 for a 3000 fL background and equal to or exceed 7:1 for a background of 100 fL; both values are based on the use of a tinted visor.

Night imagery: The contrast ratio shall be equal to or exceed the value calculated from the required number of square-root-of-two greyshades in system specification for 0, 1, 10, and 100 fL backgrounds.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.9.3. Apparatus

A photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less, and photopic and scotopic filters, a greyscale test pattern, and the contractor's flight symbology pattern (stroke) generator are required.

3.1.3.2.9.4. Procedure

Imagery -- Using the greyscale test pattern (paragraph 3.1.3.2.6.4.) in a dark room, the photometer is aligned with the darkest greyshade in the center area of the display. The contrast controls are adjusted for the maximum contrast, and the brightness controls for the lowest luminance. The brightness controls are increased until the black level (darkest greyshade) measures approximately 0.001 fL (or the lowest value possible). The white greyshade is measured and the contrast ratio calculated.

The contrast control then is adjusted to the lowest setting and the above procedure repeated measuring the darkest and lightest greyscale values. (Note: The calculated minimum contrast values could approach 1:1).

The above procedure is repeated with the contrast control in the maximum position, increasing the luminance of the darkest greyshade by an approximate factor of 10 until the maximum contrast ratio is reduced to approximately 2:1 or less, or the maximum brightness control level is reached.

Symbology (stroke) -- The contrast ratio shall be calculated for backgrounds of 100, 1000, and 3000 fL. The luminance of the symbology is measured with a photometer ASBO using an acceptance aperture of less than one-half the visible width of the symbology. The measurement is made in a dark room. The minimum and maximum adjustable luminance values are recorded.

3.1.3.2.9.5. Analytical method

The maximum and minimum contrast ratios (CR) are calculated for 10, 100, 1000, and 3000 fL backgrounds. The calculations of contrast ratio shall be performed with and without tinted visors. The equation is used:

$$CR = [L_s + G_a + (T_s T_v L_b)] / [L_b + G_a]$$

where CR = contrast ratio
L_s = symbology luminance (measured)
G_a = adjusted glare luminance for background value
T_s = IHDS see-through transmission, without visor
T_v = visor transmission (clear or tinted)
L_b = background luminance

[Note: The procedure for measuring the luminance of the stroke symbology utilizes a dark room. Under high photopic conditions, extraneous reflections will decrease the actual contrast of the symbology. The minimum and maximum glare luminance values calculated in paragraph 3.1.3.2.4., (Display extraneous reflections), shall be adjusted proportionally for the luminance background values and used to calculate the contrast ratios given in specifications for a given ambient illumination.]

Plots of the measured and calculated contrast ratios shall be made for the different background luminances for imagery and stroke symbology.

3.1.3.2.10. Display exit pupil size

3.1.3.2.10.1. Objective

To determine the size (diameter) and shape of the exit pupil of the display's optics. Both on-axis and off-axis measurements shall be performed.

3.1.3.2.10.2. Criterion

The on-axis exit pupil diameter shall be large enough to prevent reduction of field-of-view or vignetting under operational conditions (e.g., vibration) for the 1st to 99th percentile target population. Recommended value is 15 millimeters.

The off-axis exit pupil diameter shall be such that no vignetting of the field-of-view shall occur for ±20 degree eye rotation.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.10.3. Apparatus

Required equipment includes a dioptometer, a thin translucent diffusing screen with center cross, an optical comparator (0.2-mm increments or smaller), an aperture of the designed size and shape of the exit pupil (or a variable aperture), and an optical bench.

3.1.3.2.10.4. Procedure

Testing is conducted at a low level of illumination with the display mounted on the optical bench. A negative contrast test pattern with light background and dark vertical and horizontal lines indicating the center of each monocular field-of-view shall be generated on the display. This test pattern also shall have markings to indicate the outer 5 degree field-of-view in 1 degree increments for every 45 degree meridian. Figure 21 shows the test pattern for a circular and rectangular rasters. Using the vertical and horizontal lines of the test pattern, the dioptometer is used to adjust the IHDS to infinity focus at the center of the display, if the IHDS design has a user diopter adjustment.

The translucent screen with a small central cross mark is mounted on a three-way axis translation table and positioned at the design eye relief and exit pupil point. The screen is translated fore and aft with fine adjustments, perpendicular to the optical axis, until the smallest bundle of rays is found. Using the comparator, the diameter of the exit pupil is measured. If the exit pupil is not circular, the maximum and minimum dimensions are measured. If the exit pupil is irregular, sufficient data points are measured to represent the shape and size of exit pupil.

A clear aperture of the size and shape of the designed exit pupil is placed in the center of the optical path between the eyepiece lens and observer at the designed eye relief position. The outer two degrees (approximately) of the field-of-view shall be visible throughout the aperture as the trained observer moves his viewing position. The outer FOV shall only be visible to the observer for one meridian at a time. The aperture may require to be repositioned vertically, horizontally, or fore-aft to locate the exact exit pupil position. If a variable aperture is used, the dimensions are measured for each meridian when the exit pupil is positioned to produce the maximum field-of-view.

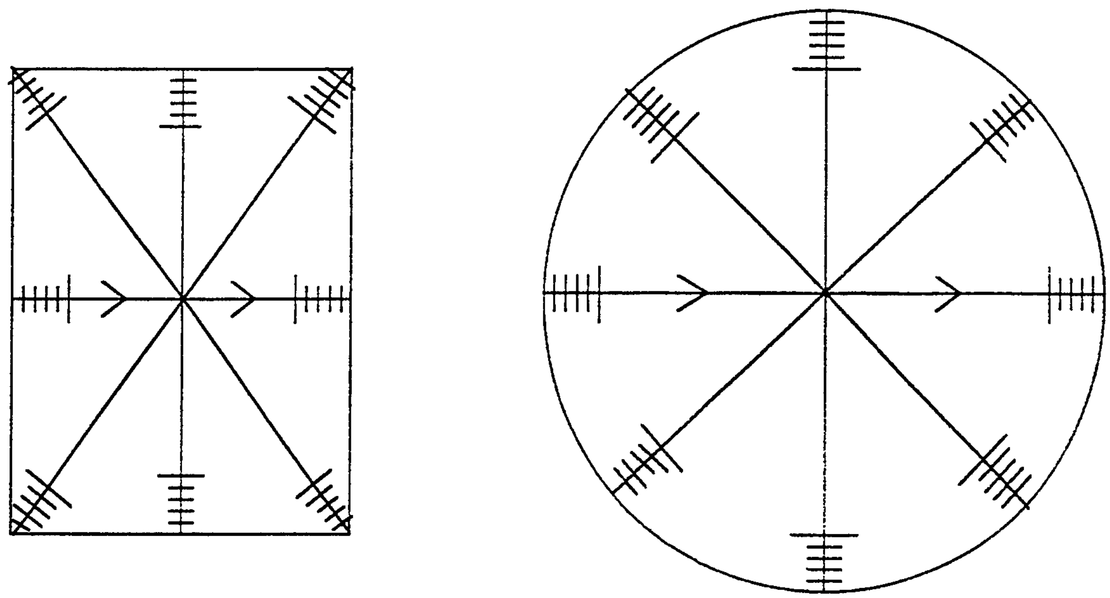


Figure 21. Cross-hair test patterns for exit pupil size and display image rotational alignments tests.

If only the display optics are available for evaluation and not the image generator (e.g., CRT), a surrogate test pattern providing the size, curvature, and luminance spectra that are equivalent to the intended display shall be used.

3.1.3.2.10.5. Analytical method

Measured exit pupil size is compared to required specifications. If a fixed aperture of the designed size and shape is used, a pass or fail criterion is used.

3.1.3.2.11. Display optical eye relief

3.1.3.2.11.1. Objective

To determine the optical eye relief distance of the display's optical design as measured from the last optical element to the exit pupil.

3.1.3.2.11.2. Criteria

The optical eye relief shall meet design specifications.

3.1.3.2.11.3. Apparatus

A millimeter ruler or caliper with 1.0 mm increments or less shall be used. The test pattern on the IHDS shall be a white background, illuminating the full field-of-view, with cross marks or other small symbology to indicate the outer field-of-view (<1 degree from the edge), the optical display center for each channel (left and right), and the designed line-of-sight, if IHDS uses partial overlapping fields of view.

3.1.3.2.11.4. Procedure

The various IHDS parameters such as diopter focus, combiner height, etc., are adjusted to nominal or specified values. The exit pupil is located with one of the following methods:

On-axis conventional system: A translucent screen with a small central point or cross mark is mounted on a three-way axis translation table and positioned at approximately the designed exit pupil point. The screen is translated fore and aft with fine adjustments, along the optical axis, until the smallest bundle of rays is found. Physical measurements are taken for the distance from the exit pupil position to the first encountered optical element along the optical axis towards the center of the monocular field-of-view. Note that the design line-of-sight and the optical axis of the IHDS may not be coincident for partial overlapping and/or off-axis display systems.

Off-axis or nonconventional systems: The translucent screen is replaced with an occluder of the shape and dimensions (minus 1 mm of the radius) of the designed exit pupil for the most peripheral rays of the system. The aperture is placed at the approximate designed eye relief point, if known, and a trained observer viewing from behind the occluder determines if the outer edges of the field-of-view are visible. The trained observer shall be able to see segments of the outer edges of the field-of-view while viewing around the occluder except those segments blocked by the support structure of the occluder. The observer will need to move perpendicular to the designed line-of-sign at angles corresponding to the designed field-of-view. Small fore-aft, lateral and vertical movements of the occluder may be required to find the optimum location. The distance from the exit pupil position and the center of the monocular field-of-view is measured.

With moveable beamsplitters and different interpupillary distances, the measured optical eye relief could change. The IHDS shall be adjusted for the minimum and maximum inter-pupillary distances and the optical eye relief remeasured.

3.1.3.2.11.5. Analytical method

Measured optical eye relief is compared to design value.

3.1.3.2.12. Display focus range

3.1.3.2.12.1. Objective

To determine the range of focus adjustment available to the user.

3.1.3.2.12.2. Criteria

A display focus adjustment capability of at least +1 to -2 diopters is recommended for nonsee-through systems. Markings indicating positive, negative, and zero focus settings shall be provided. A zero value setting marking shall be provided for user awareness.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.12.3. Apparatus

A dioptometer with a minimum range of ±1.0 diopter and 0.25 diopter calibration scale is used. Trial lenses with diopter values of +2.00 and -1.00 may be required.

3.1.3.2.12.4. Procedure

The eyepiece of the dioptometer is adjusted and calibrated to the evaluator's eye. The user adjustable IHDS focus is set at one of the maximum positions. The evaluator views the IHDS through the dioptometer. Using the dioptometer focus and trial lenses (if required), the IHDS imagery is brought into focus. The required total diopter setting adjusted for the trial lenses is recorded. These steps are repeated with the IHDS set to the opposite extreme user adjustable focusing setting.

The presence of definable focus indicator markings is noted.

3.1.3.2.12.5. Analytical method

The measured focus adjustment range shall be compared to test criteria.

3.1.3.2.13. Display spherical/astigmatic aberration

3.1.3.2.13.1. Objective

To determine the residual refractive power of IHDS with lateral and vertical displacement of the eye when measured at the designed exit pupil.

3.1.3.2.13.2. Criteria

Refractive residual spherical and astigmatic power shall be minimized within the designed exit pupil of the IHDS. Using a 5-mm entrance pupil, suggested values of maximum variability for spherical and astigmatic errors are 0.50 diopters and 0.37 diopters, respectively, within 4 mm of displacement perpendicular to the designed line-of-sight of the HMD, and no more than 0.75 diopters of spherical or astigmatic variation within the nonvignetted exit pupil. Measurements are made at the center of the binocular field-of-view (aligned with the designed line-of-sight), at the center of each monocular field-of-view (aligned with the optical axis), and at 3/4 of the distance from the center to the edge of the monocular fields-of-view positions. Note: For partial overlapping binocular or biocular displays, the designed right and left channel lines of sight and the optical axes will usually not coincide.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.13.3. Apparatus

A dioptometer with 0.125 diopter increments or less and a 5-millimeter entrance aperture and a 16-spoke wheel (15-degree increments between spokes) test pattern projected on the IHDS. The size of the spoke wheel pattern shall appear at least 5 degrees in diameter ASBO through the dioptometer. The test pattern shall be moveable within the field-of-view or duplicated at the designed testing points in the field-of-view and mounting hardware for dioptometer with 2-axes movement (vertical and horizontal) in 1-mm increments or less.

3.1.3.2.13.4. Procedure

A trained observer aligns the dioptometer on the designed line-of-sight of the IHDS with the aperture of the dioptometer at the designed exit pupil of the system. Initial measurements are made at the center of the binocular field-of-view around the designed line-of-sight. Measurements are made, checking for both spherical and astigmatic residual refractive power. The dioptometer is moved laterally in both directions from the line-of-sight in 2-mm increments. Diopter values at the meridians of maximum and minimum power are recorded at each position. Likewise, beginning at the designed line-of-sight of the IHDS, the dioptometer is moved vertically in both directions in 2-mm increments and readings recorded. The range of movements are continued until vignetting is observed through the dioptometer.

The spherical and astigmatic power through the IHDS also are measured when the diopterscope is aligned to measure the residual refractive error at the center and at 3/4 the distance from the center to the edge of each monocular field-of-view. The number of necessary measurements made at the 3/4 distance points and the number of points per ocular shall be

determined by the particular IHDS design and the measured variability with one of the optical channels (assuming the right and left oculars are essentially the same, but right and left components reversed).

3.1.3.2.13.5. Analytical method

The range of spherical and astigmatic refractive errors are compared to test criteria.

3.1.3.2.14. Display image rotational alignment

3.1.3.2.14.1. Objective

To measure image rotation ASBO to a vertical referenced plum line for right and left optical channels of the IHDS. If image rotation is user adjustable, then the range of rotation shall be measured.

3.1.3.2.14.2. Criteria

The difference in rotation between the right and left IHDS channels of a cross-hair pattern at the edge of the field-of-view shall not produce more than 3 milliradians (10 arc minutes) of misalignment, measured perpendicular to the meridian. An acceptable absolute value between the real image and the display rotation for either channel has not been fully investigated. A suggested maximum value is 2 degrees of rotation.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.14.3. Apparatus

A pattern generator capable of providing a cross-hair test pattern (Figure 21) with 8 meridians (45 degrees of rotation per meridian) shall be used. The vertical meridians shall be marked as to be distinguished from the other meridians. Cross-hairs shall extend to the edge of the full field-of-view. An additional projected or real cross-hair pattern identical to the generated pattern, sized to cover the IHDS field-of-view at a viewing distance of 3 or more meters, shall serve as the reference.

To improve accuracy and to measure small deviations, a telescope of 5X or greater and/or a calibrated charge-coupled device (CCD) camera with associated image processing software may be used.

3.1.3.2.14.4. Procedure

The IHDS is mounted rigidly and mechanically aligned such that the designed line-of-sight is parallel to the floor and aligned with the center of the reference cross-hair target in all axes. Since the viewed virtual cross-hair target would probably be aligned at infinity, each channel can be tested independently. The real target, when located at a distance less than infinity, would have to be displaced laterally when beginning testing of the other visual display channel in order to compensate for the viewer's IPD. The real target cross-hair shall be aligned using a plum line.

The observer adjusts the IHDS according to the manufacturer's instructions and views the real target cross-hair. The brightness of the IHDS display and the real cross-hair target are adjusted such that both are easily visible. The real target is moved laterally until the centers of the real and virtual cross-hairs coincide for the eye channel being tested.

If the rotation of the display is not user adjustable (either mechanically or electronically), the vertical and horizontal cross-hairs ASBO are marked on the background of the real cross-hair target at approximately 75 percent of the field-of-view for both height and width. If the rotational deviations are not regular, multiple points shall be required to show the shape of the vertical, horizontal and diagonal lines. A least squares curve fit shall be used to describe the rotation.

The vertical, horizontal, and diagonal angles of rotation from the display ASBO in relation to the plum line-of-the real target are measured or calculated for each channel. The angular deviation from the real cross-hair at the edges of the total display field-of-view, perpendicular to the vertical and horizontal axes, is measured or calculated.

If the image from the IHDS is rotatable by the user, the amount of possible rotation, both clockwise and counterclockwise shall be measured and recorded.

3.1.3.2.14.5. Analytical method

For a nonadjustable image rotation system, the measured values shall be compared to test criteria.

3.1.3.2.15. Display image size disparity

3.1.3.2.15.1. Objective

To determine if images from the right and left channels of the IHDS are of equivalent apparent size.

3.1.3.2.15.2. Criteria

Deviations of corresponding image points to each eye as seen by the observer (ASBO) shall not exceed 3 milliradians (10 arcminutes) at the edges of the displays, or any differences in horizontal and vertical image dimensions shall not exceed 1.5 percent, whichever is smaller.

Additional or alternate criteria from specification documents shall be used for this test where required.

3.1.3.2.15.3. Apparatus

This test requires an electronically generated test pattern similar to the one used for the rotational alignment with the addition of 3 milliradian squares presented to 1 eye and 3 milliradian "plus" signs (+) presented to the other eye (Figure 22). The squares and "+" signs shall be located every 2 degrees within the overlapped fields-of-view. The contrast of the squares and "+" signs shall be opposite to prevent fusion by the observer.

Note: If the IHDS sample system uses partial overlapped oculars, the test patterns generated may have to be centered at the designed line-of-sight and electronically predistorted to compensate for residual distortions from the intended sensors. That is, the sensor may have deliberate pincushion distortion, and the display would have an equal amount of barrel distortion such that the two distortions cancel one another. To evaluate both distortion and image size disparity, the equivalent distortion from the intended sensor will have to be induced into the IHDS electronic input.

Also required are: a slide projector with target slide for see-through vision depicting irregular patterns of medium and high spatial frequencies with no repeating patterns (pictures of outside scenes of trees and bushes are suitable examples); two 60 mm diameter +0.25 spherical lenses with 0.8 base-in prism diopters; IHDS mounting hardware; and a viewing screen or wall subtending at least 40 x 40 degrees at 4 meters.

3.1.3.2.15.4. Procedure

The IHDS is secured in a forward normal line-of-sight position and properly adjusted for focus and alignment. The IHDS and background projected images are adjusted in luminance such that both are visible easily. The projected image that is viewed with see-through vision is located 4 meters from the observer. The +0.25 spherical lenses are positioned in front of the IHDS to optically adjust accommodation and convergence to infinity for the see-through image. The observer reports the presence of the "+" signs outside the 3-milliradian boxes.

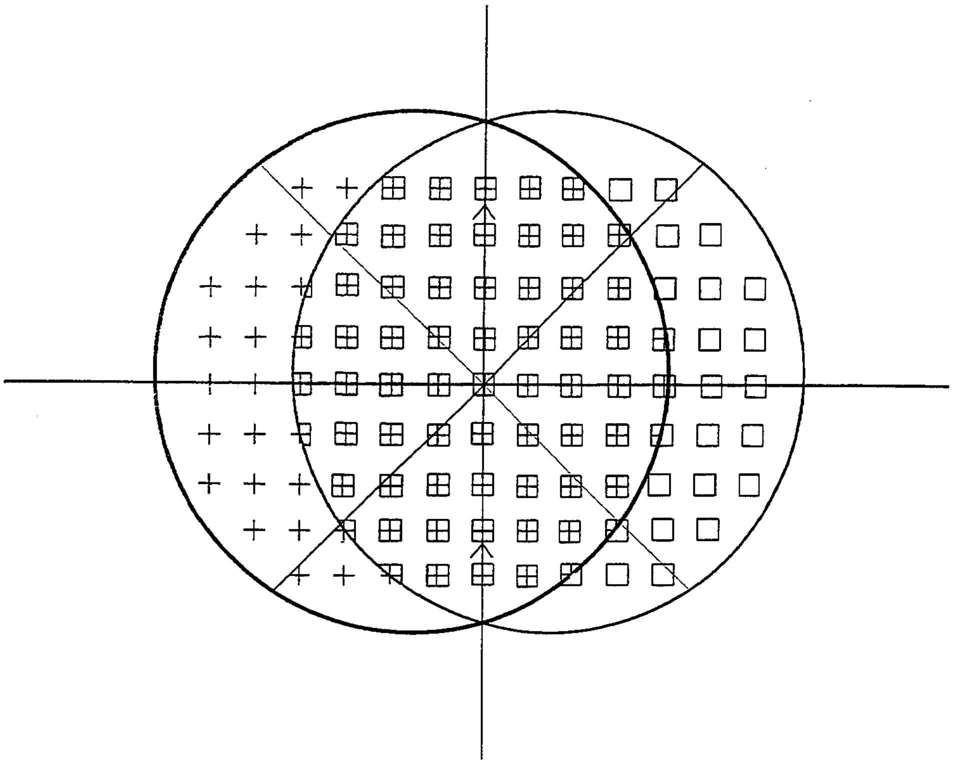


Figure 22. Display image disparity test pattern.

An alternate method would use a cross-hair in both channels at the designed line-of-sight and concentric circular patterns displayed through each channel of the IHDS. The right and left channel circular images would be of opposite contrast to prevent fusion, but the cross-hairs would be of the same contrast. The interval between circles would be 5 degrees with the outer circle located within 5 degrees of the IHDS total field-of-view. The width of the lines to create the concentric circles shall be as small as possible. Both right and left test patterns shall have the positive contrast target used for display rotation included in the pattern. The lenses used to set the observers accommodation and convergence at infinity are positioned in front of the IHDS. The apparent diameters of the circles are marked on a wall using eight points per circle and compared in size between the right and left imaging channels.

A 5X or greater telescope or CCD camera may be used to improve accuracy.

3.1.3.2.15.5. Analytical method

For the first procedure using the "+" in one channel and the squares in the other, image sizes shall be compared with specifications on a pass/fail criterion. The amounts of size differences between the displays can be estimated with the 3- milliradian targets. With the alternate method, the size differences can be measured.

3.1.3.2.16. Display vertical and horizontal image alignment

3.1.3.2.16.1. Objective

To measure difference in vertical and horizontal positioning of imagery and/or symbology produced by the two channels of the IHDS.

3.1.3.2.16.2. Criteria

Maximum vertical deviation between the centers of the displays or central corresponding points for imagery shall not exceed 0.18 prism diopter (1.8 mr, 6.12 arcminutes). For day symbology presented to both eyes, maximum vertical deviation shall not exceed 0.1 prism diopter (1 mr, 3.4 arcminutes) with both clear and tinted visors.

Maximum horizontal deviation between the centers of the displays or central corresponding points for imagery shall not exceed more than the equivalent of 0.50 diopter (5 mr, 17 arcminutes) of base out prism or 0.18 diopter (1.8 mr, 6.2 arcminutes) of base in prism. For day symbology presented to both eyes, maximum horizontal deviation from a real object ASBO shall not exceed 1 milliradian for clear and tinted visors.

Note: The user may have to have a control for vertical and horizontal display movement to obtain this alignment criteria for binocular symbology with 2 image generators and see-through vision. If user has alignment adjustments, alignment shall be achievable within approximately the middle 3/4 of the total range adjustment for both horizontal and vertical positioning. A user adjustment alignment range of ±5 mr in the vertical and horizontal is suggested. If adjustments are in fixed increments, the increments shall be less than 1 milliradian, and preferably 0.5 milliradians.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.16.3. Apparatus

Testing is conducted using an operating IHDS with clear and tinted visors. Additional equipment includes: electronically generated cross-hairs or small positive contrast target located at the designed line-of-sight of each channel, parallel telescopes with cross-hair reticles, and a screen with cross-hair at a viewing distance of greater than 4 meters. Either the electronic or telescope cross-hairs shall have central lines marked off in 1-milliradian (mr) increments with a minimum of 10 mr range. Mirrors or 90 degree prisms with mounting hardware may be required to align telescopes with the design line-of-sight of the IHDS.

3.1.3.2.16.4. Procedure

Imagery: The cross-hair test pattern is generated in the IHDS for the design line-of-sight. The parallel telescopes are positioned with their objective lenses as near as possible to the design exit pupil of the IHDS and along the design line-of-sight. If mirrors or prisms are necessary, alignment without the IHDS shall be required for calibration.

Viewing through the parallel telescopes, the cross-hairs of the telescopes are aligned with one of the cross-hairs from the IHDS. The difference in alignment with the other display's cross-hair is recorded for both vertical and horizontal deviations.

If IHDS has IPD and vertical adjustments, measurements of alignment shall be taken at all combinations of the minimum, maximum, and midpoint values.

If the IHDS has user adjustments for vertical and horizontal alignment, the range of the adjustments either mechanical and/or electronic will be estimated. This range of adjustment may be plotted if IHDS has see-through vision using a viewing screen or wall four or more meters away.

Symbology with see-through vision: This test shall be performed alternating with the clear and tinted visors in place. The background and/or display luminance shall be adjusted for compatible visibility with the clear and tinted visors. If IPD and vertical position are adjustable, an initial IPD setting of 65 mm and midrange vertical positioning are suggested. A cross-hair test pattern target is generated on the IHDS in the center of the field-of-view. The objective lenses of the parallel telescopes are positioned at or near the designed exit pupils of the IHDS and aligned along the design line-of-sight.

At four meters or greater a fixation target of less than 1-milliradian diameter is positioned on a viewing wall. Viewing through one eye (right) of the parallel telescopes, the IHDS or test target is moved laterally and/or vertically until the test pattern IHDS generated cross-hair is aligned with the small fixation target on the wall. The parallel telescopes also may require adjusting to align with the IHDS designed line-of-sight. Viewing through the opposite tube (left) of the parallel telescope, the amount of deviation in millimeters of the IHDS cross-hair from the small fixation point on the viewing wall shall be recorded. With no horizontal deviation, the measured displacement value would be equal to the IPD setting or 65 mm horizontally from the fixation point for this example and at the same height if the IHDS images were aligned for infinity.

If the IHDS relative vertical and horizontal image alignments are user adjustable, the observer shall attempt to align the cross-hairs at infinity and measure any residual deviations. The range and increments of adjustment available also may be measured.

If the IHDS relative image alignment is not user adjustable, then the procedure is repeated by aligning the opposite cross-hair (left) in the IHDS with the fixation point on the wall by readjusting the position of the IHDS. Both channels are measured five times each.

This procedure is repeated for minimum and maximum IPD values, adjusting the parallel telescopes and IHDS as required.

Note: The determination of the disparity of the alignment between the right and left channel of the IHDS for an infinity setting is dependent on the IPD and vertical settings. For example, if the IPD setting is 65 mm, then the cross-hair as seen through the display shall be located 65 mm from the fixation point on the same side, and at the same vertical height. A change in vertical adjustment also shall displace the line-of-sight proportionally. If special lenses are placed in front of the IHDS to adjust accommodation and convergence to infinity for the given viewing distance, then the disparity is adjusted only for the difference in IPD values.

Alternate apparatus and procedures shall have a resolution of 0.5 milliradians or better.

3.1.3.2.16.5. Analytical method

The means of the five measurements for vertical and horizontal alignment differences between the right and left channels for each IPD position are compared with applicable criteria.

3.1.3.2.17. Display distortion

3.1.3.2.17.1. Objective

To quantify the right and left channel mapping of imagery ASBO, and determine if geometric correction circuits have been incorporated to sufficiently compensate for probable sensor, electronic, and/or optical distortion. Note that the display distortion may have been induced to offset the distortion in the intended sensor.

3.1.3.2.17.2. Criteria

For monocular IHDS and biocular/binocular optical systems with fully overlapped fields of view, an overall 4 percent distortion value has usually been considered acceptable. That is, a deviation in image mapping towards the periphery of the display could be off by 4 percent, providing the deviation is gradual with no noticeable irregular waviness of vertical or horizontal lines. For a projected display of 40 degree circular field-of-view and 4 percent distortion, this would mean an object at the edge of the visible field-of-view could appear at 40 x 1.04 (41.6 degrees-- pincushion distortion) or 40/1.04 (38.5 degrees -- barrel distortion).

With biocular/binocular IHDS for overlaying symbology, the IHDS will have to meet head-up display specifications of 1 milliradian or less difference between the right and left image channels for symbology within the binocular overlapped area if the symbology is seen by both eyes. Otherwise, diplopia and/or eye strain will be induced.

When imagery is used with a minimum see-through requirement, the maximum displacement between the right and left image points within the biocular/binocular region shall not exceed 3 milliradians (0.3 prism diopter) for vertical, 1 milliradian (0.1 prism diopters) for divergence, and 5 milliradians (0.5 prism diopter) for convergence.

A quantified value for acceptable irregular distortion with imaging devices has not been determined. However, if irregular distortion or diplopia is detected by the trained observers within the binocular area of the display and/or within 20 degrees of the designed line-of-sight, the distortion probably would be considered unacceptable.

In addition, systems using I^2 tubes with fiber optic twists may produce shear effects or "S" distortion, which is covered in NVG tube specifications.

Additional or alternate criteria from specification documents will be used for this test where required.

3.1.3.2.17.3. Apparatus

Electronic generated test patterns, predistorted to match input from intended imaging sensor, are required. Two test patterns, one of thin vertical lines and one of thin horizontal lines, moveable both in the vertical and horizontal directions will be used. The vertical and horizontal lines shall be separated by approximately 5 degrees. The vertical and horizontal lines initially located in the center of the field-of-view shall be marked to distinguish them from the other lines in the pattern.

A central cross-hair and the vertical and horizontal IHDS field-of-view limits shall be marked on a viewing wall approximately 4 meters away for reference. Plus (+) lenses (+0.25 diopters for 4 meters) and base in prisms (IPD (cm)/distance (meters) = total prism diopter requirement) shall be used if the IHDS is biocular/binocular to provide infinity convergence and accommodation for see-through vision at the viewing distance.

Since distortion could be a function of interpupillary distance for a biocular/binocular IHDS, 3 trained observers shall be used, with approximately 5, 50 and 95 percentile IPD values (60, 64, and 68 mm).

Where possible, a still camera will be used to record distortion.

3.1.3.2.17.4. Procedure

The test patterns for the vertical and horizontal lines are generated on the IHDS electronically to accurately simulate the image mapping of the intended sensor. These lines shall be separated at equal angles through out the display field-of-view. A trained observer with good resolution and stereopsis centers the line-of-sight of the IHDS using the cross-hair and field-of-view outline on the viewing screen. The IHDS then is fixed in position. Monocularly, the observer looks for tilting and

irregular bends in the displayed vertical lines throughout the field-of-view. If no distortion is noted, the vertical lines are shifted electronically approximately 1/5 the separation distance between the vertical lines and the inspection for distortion is repeated. When distortion is detected, the location of the distortion is marked and recorded in horizontal degrees from the center of the field-of-view. The technical observer then moves the IHDS (yaw axis) until the vertical display line with distortion coincides with the cross-hair line seen with see-through vision. By directing the assistant, a plot of the distorted display line is made and calculated in milliradians of horizontal deviation from the true see-through line. The procedure is repeated for the other eye.

The horizontal lines also are evaluated for distortion with their positions incremented through the field-of-view. The locations and amounts of maximum distortion, irregularities, and diplopia are recorded.

In the biocular/binocular portion of the field-of-view, there may be stereo distortions or diplopia such that the vertical display lines do not lie at infinity (simulated or real). Again, the plus lenses and base in prism to simulate infinity convergence and accommodation with see-through vision are used with a blank background at least 1.5 times the focal distance of the infinity simulating lenses (i.e., 6 meters when using the 0.25 diopter auxiliary lenses). The assistant would place a rod/pole at the observer's perceived depth of the display vertical lines recording separately the distance to the top, center, and bottom of the display lines in the vertical field-of-view.

To search for the maximum deviations in depth perception from the simulated infinity, the vertical lines are repositioned electronically in approximately 1/5 the distance between vertical lines. The perceived distances to the display vertical lines are recorded as absolute distances from the focal length of the infinity simulation lenses.

Where possible, photographs of the virtual and real test patterns will be taken for each eye for documentation.

3.1.3.2.17.5. Analytical method

If distortion is detected by the trained observers, distortion maps shall be made for the IHDS field-of-view. One distortion map will show calculated angular displacement of the vertical and horizontal display lines from the true angular projection, and another distortion map will show the absolute distances of the perceived display vertical lines.

3.1.3.2.18. Display luminance uniformity

3.1.3.2.18.1. Objective

To determine the luminance profile of the display.

3.1.3.2.18.2. Criterion

The luminance at any 2 points within a flat field presented on the display shall not vary by more than 20 percent.

Additional or alternate criteria from specification documents shall be used for this test where required.

3.1.3.2.18.3. Apparatus

A photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less, and photopic and scotopic filters is required.

3.1.3.2.18.4. Procedure

A flat field (uniform background) is presented on the display. Nine square sections of equal size are located on the display at the center of the display and at approximately 3/4 of the distance to the edge of the display along meridians defined by the vertical, horizontal, and diagonals of the display shown in Figure 18. The photometer is used to measure the mean luminance about the center of each section.

3.1.3.2.18.5. Analytical method

The luminance values for all nine sections shall be normalized and presented as percentages of the maximum value. These percentages shall be compared to test criterion.

3.1.3.2.19. Display static modulation transfer function (MTF)

3.1.3.2.19.1. Objective

To determine the modulation transfer function (MTF) of the raster display at low, medium, and high luminance settings at the center and a point 75 percent of the distance from the center to the edge of the field-of-view. Suggested mean values for low, medium, and high luminance are 0.1, 1.0, and 10.0 fL, respectively. Display MTF shall include all display components from the imaging source up to and including the display optics.

3.1.3.2.19.2. Criteria

For imagery, the display shall not decrease the sensor/ electronic overall MTF or the limiting resolution at the 10 percent modulation point by more than 10 percent at the specified luminance levels in the designed line of regard. Off-axis and peripheral field decreases in MTF shall be less than TBD percent.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.19.3. Apparatus

Both the discrete and Fourier methods use an EG&G Gamma Scientific* digital spatial scanning microphotometer system. This system consists of: model GS-4100 radiometer, model GS-2110A telemicroscope (with 25 x 8000 micron slit aperture), a photomultiplier tube (PMT), SPATL-C11/MTF software, a host computer, and associated lenses, shutters, and apertures. A video source capable of producing input waveforms of a greyscale (stairstep) pattern (video signal of 1 volt peak-to-peak), a horizontal knife edge (low spatial frequency pattern), an impulse (vertical spot profile), or bar patterns of spatial frequency of 0.2 cycles/millimeter to approximately 50 cycles/millimeter. The upper spatial frequency value is dependent on the display performance and shall be defined as the spatial frequency at which the modulation is approximately 1 percent.

3.1.3.2.19.4. Procedure

MTF can be measured using one of several objective techniques: the discrete method and Fourier transform methods where the MTF is obtained by taking Fourier transform of the luminance profile of an impulse or knife edge input waveform. Verona (1992) recommends the discrete method over the alternate techniques.

Discrete method: Using a greyscale (stairstep) video signal of 1 volt peak-to-peak, the brightness and contrast controls are set such that the active raster background luminance is 1 percent of the peak luminance. A sine wave video signal for a specific spatial frequency is applied to the CRT display. The resulting modulation is measured with a scanning microphotometer. The measured highlight and black level values are used to calculate the modulation contrast. This procedure is performed for each spatial frequency from 0.2 cycles/millimeter until the modulation contrast falls to less than 1 percent.

Knife edge Fourier method: Using a greyscale (stairstep) video signal of 1 volt peak-to-peak, the brightness and contrast controls are set such that the active raster background luminance is 1 percent of the peak luminance. A low spatial frequency (0.2-0.5 cycles/millimeter) video signal is used to produce a small number of bars on the display. The scanning photometric microscope with a 25 x 8000 micron slit aperture is moved in 4-micron steps from the middle of a black bar across a transition into a white bar (knife edge), measuring the light amplitude at successive points. Under software operation, the host computer positions the aperture, opens and closes the PMT detector shutter, reads the PMT signal, performs required calibration, and stores the adjusted readings in a spatial data file. A fast Fourier transform algorithm is used to compute the MTF. The Fourier transform of the light intensity profile produces a representation of the amplitude components of each spatial frequency.

Impulse Fourier method: Using a greyscale (stairstep) video signal of 1 volt peak-to-peak, the brightness and contrast controls are set such that the active raster background luminance is 1 percent of the peak luminance. A single horizontal scan line is generated on the face of the display. The scanning photometric microscope with a 25 x 8000 micron slit aperture (with the long slit axis parallel to the line) is moved in 4 micron steps across the line, measuring the light amplitude at successive points. Under software operation, the host computer positions the aperture, opens and closes the PMT detector shutter, reads the PMT signal, performs required calibration, and stores the adjusted readings in a spatial data file. A fast Fourier transform algorithm is used to compute the MTF. The Fourier transform of the light intensity profile produces a representation of the amplitude components of each spatial frequency.

3.1.3.2.19.5. Analytical method

The MTF is presented as a graph depicting the modulation transfer factor for spatial frequencies over a range from zero to where the modulation transfer factor approaches zero (Figure 23). The display MTF is compared to the sensor MTF.

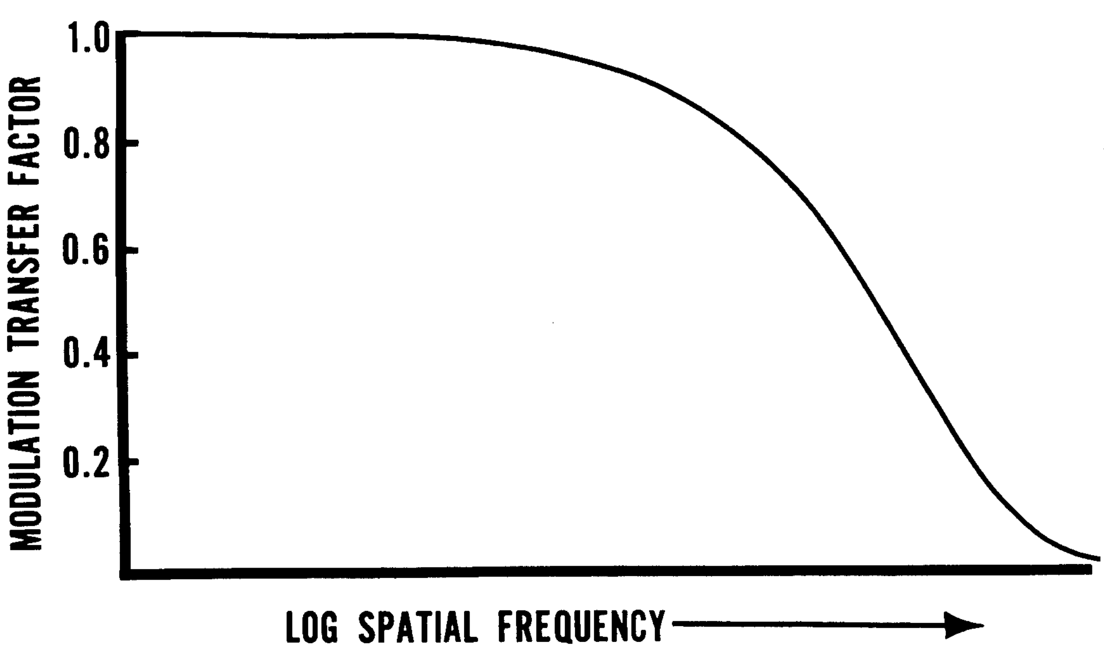


Figure 23. Typical modulation transfer function (MTF) curve.

3.1.3.2.20. Display dynamic modulation transfer function (DMTF)

3.1.3.2.20.1. Objective

To measure any degradation in the static MTF of the display that occurs due to the dynamic (temporal) characteristics of the display, relative motion within the targeting scene, and/or relative motion between target and sensor. For CRT based displays these characteristics include phosphor rise time and persistence, horizontal scan rate, and vertical field rate; characteristics for flat-panel displays include addressing cycle time, temperature dependent crystal mobility, and suspension media viscosity (Rash and Verona, 1987).

3.1.3.2.20.2. Criteria

There shall be no degradation in the static MTF caused by image smearing, shearing or serrations for relative target/sensor or relative motion within the targeting scene for relative velocities up to 30 degrees/sec. For velocities greater than 30 degrees/second, there shall be no visibly perceptible dynamic image degradation.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.20.3. Apparatus

Drifting sine wave technique: Measurements are performed using: an EG&G Gamma Scientific digital microphotometer system consisting of a model GS-4100 radiometer, model GS-2110A telemicroscope, a model D-46 photomultiplier tube (PMT) with 4 MHz amplifier, SPATL-C11/MTF software, a host computer, and associated lenses, shutters, and apertures; a Tektronix*, model 2440, digital storage oscilloscope; a Visual Information Institute model 542 signal source, model PG 508 dual sync/pedestal generator, model FG 504 function generator, and model DC 505A universal counter; and a drift rate timing circuit. A box diagram for this instrumentation set up is provided in Figure 24a.

The dual sync/pedestal generator produces pulses (H drive, V drive, blanking, and sync) at either a 525/60 or a 875/60 scan rate, as selected. It also produces a horizontal function gate at a controlled deviation rate from the sync generator oscillator which is used to synchronize the pulse generator, sine wave generator, counter, and the drift rate timing circuit. It also contains a pedestal generator to convert the oscillator output into a composite or a noncomposite video signal format, as selected by a front panel switch. Movement at the drift rate control produces an image which can be drifted either left or right. When the desired drift rate is reached, its value can be determined by measuring the output of the drift rate timing circuit (utilizing a Tektronix model 244 oscilloscope). The modulation frequency is generated and controlled by the function generator (FG 504). The

pulse generator (PG 508) provides the proper pulse width, amplitudes, and polarity required by the function generator. The universal counter (DC 505A), is used to determine the modulation frequency generated by the function generator.

The drift rate timing circuit is a discrete circuit which utilizes the horizontal drive pulse and the function gate to generate a pulse that is a measure of the time it takes one frame width to move across the CRT.

Counterphase modulation technique: This technique uses a HP-98731 Turbo-SRX computer graphics workstation; EG&G model D-46A photomultiplier tube, DR-2 digital radiometer, model 700-10-52 scanning micrometer, and associated shutters, filters, and apertures; and Wavetek, model 432, dual hi/lo filter; and a Tektronix, model 2440, digital storage oscilloscope.

A box diagram of the experimental setup is presented in Figure 24b. Stimulus generation is performed using a computer graphics workstation linked to a video scan converter. Measurement of the resulting display peak and trough luminances, which are used to calculate the modulation contrast values, is accomplished using a combination of collection optics, a photomultiplier tube (PMT), a high voltage supply, electronic filters, and a digital storage oscilloscope.

Stimulus patterns are generated with a Hewlett-Packard model HP-98731 Turbo-SRX computer graphics workstation. The output of the computer is fed to a Folsom Research, Inc. model 8910 color graphics converter which produces a RS-170A NTSC video signal. This video signal is used to drive the display under evaluation. The software which produces the stimulus patterns is written in the C programming language running in an UNIX environment. Except for aliasing effects, the patterns theoretically can be generated at any desired spatial frequency and presented at any temporal frequency at or below 30 Hertz.

3.1.3.2.20.4. Procedure

Two procedures may be used to measure dynamic MTF. The first of these procedures, referred to as a drifting sine wave technique, can be used on standard CRTs and flat-panel technology displays which accept NTSC input. The second technique, referred to as a counterphase modulation technique, is applicable to digital displays.

Drifting sine wave technique: This procedure is based on modeling relative target/sensor motion as a display pixel responding to a spatial frequency S moving across the display at a linear speed V (Rash and Becher, 1982). This results in the intensity of the pixel being modulated at a temporal frequency of SV. Linear drift velocities of 0.01, 0.1, and 1.0 display widths per second are used. Spatial frequency values range from 2-5 to 200 cycles per display width or until the modulation contrast (M_c) drop off to less than 5 percent (0.05).

The first step is a predetermination of peak brightness. For the simulated night environment, a value of 15 footlamberts is recommended. Brightness and contrast controls are adjusted to their

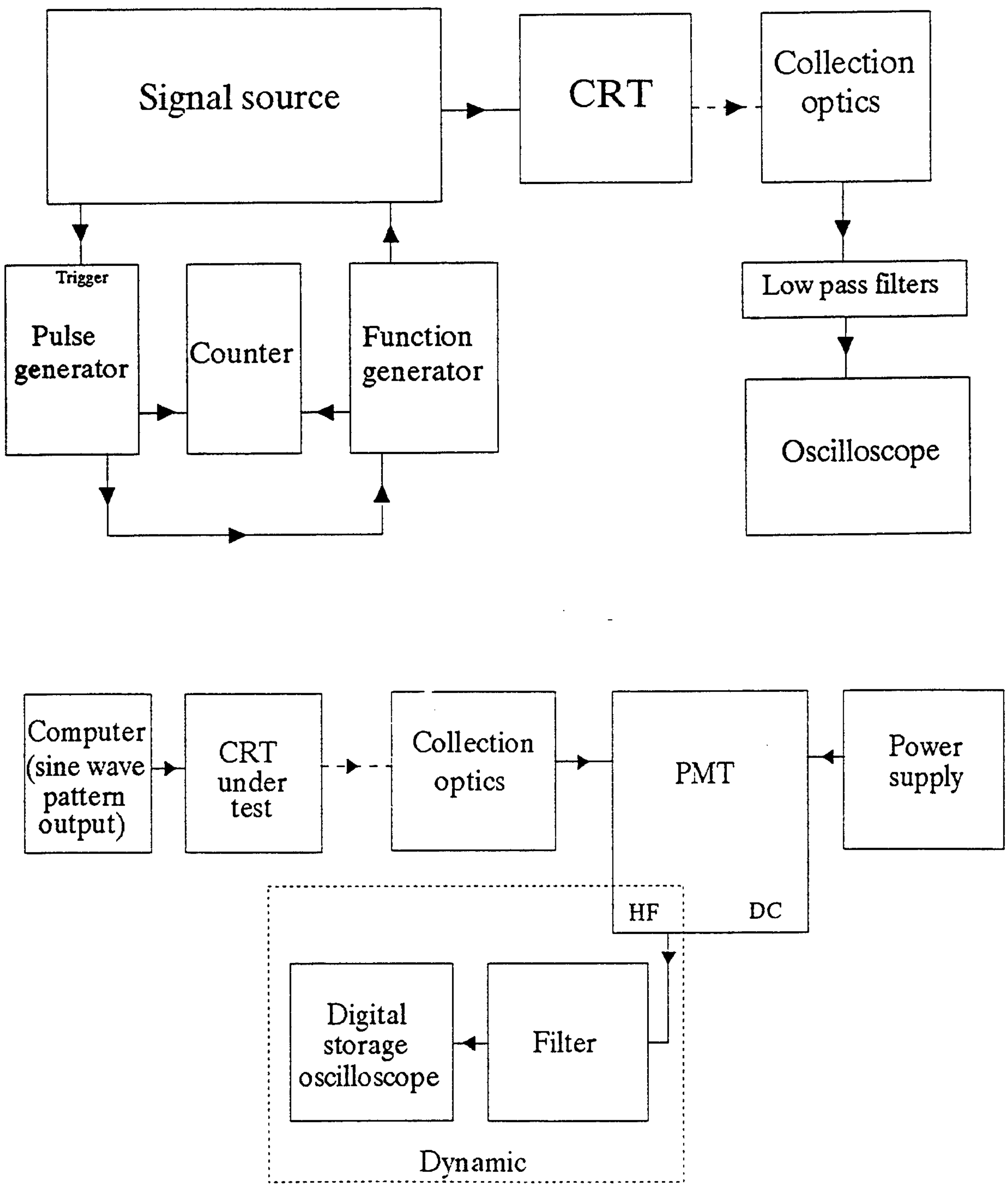


Figure 24. Block diagrams of experimental setup for measurement of dynamic modulation transfer function using a) drifting sine wave and b) counterphase modulation techniques.

minimum settings (fully counterclockwise). Inputting a low spatial frequency square wave 1-volt peak-to-peak video signal, the brightness control is increased until the raster is just barely visible. The contrast control then is advanced to a setting which produces a 15 footlamberts luminance value at the peak of the pattern (maximum video level). The black level luminance (minimum video level) is examined to see if the 0.15 footlambert value is present. As required, the brightness and contrast controls are adjusted alternately to achieve the 100:1 ratio.

The microphotometer is positioned and focused at a point at or near the center of the display under test. For the first selected drift velocity, the first spatial frequency (typically 2-3 cycles/display width) stimulus is produced on the display. As the luminance pattern moves pass the microphotometer, the photometer output signal is acquired using the storage oscilloscope. From the digitized waveform, the peak and trough values are obtained and used to calculate the modulation contrast value. This procedure is repeated for each spatial frequency. The measurement sequence for the range of spatial frequencies is repeated for the remaining drift velocities.

Counterphase modulation technique: For the simulated night environment, a peak display value of 15 footlamberts is established. For a desired white/black ratio of 100:1, this requires the black level luminance to be 0.15 footlambert. Brightness and contrast controls are adjusted to their minimum settings (fully counterclockwise). Inputting a low spatial frequency square wave 1-volt peak-to-peak video signal, the brightness control is increased until the raster is just barely visible. The contrast control then is advanced to a setting which produces a 15 footlamberts luminance value at the peak of the pattern (maximum video level). The black level luminance (minimum video level) is examined to see if the 0.15 footlambert value is present. As required, the brightness and contrast controls are adjusted alternately to achieve the 100:1 ratio.

The test imagery presented on the display of the HMD is dynamic sine wave spatial patterns generated by with the long dimension of the pattern at a 90° angle (vertical) to the display's scan line structure. The spatial sine wave patterns are modulated temporally at selected sinusoidal frequencies. One temporal cycle of the stimulus consisted of the luminance at a position on the display changing from its brightest value to its darkest value and back to its brightest value (counterphase). As a result, the luminance variations on the display are sinusoidal in both spatial and temporal domains. (Note: This temporal sinusoidal test stimulus is different from a square wave counterphase flicker stimulus where the luminance at a point on the display is alternated in a square wave fashion with abrupt transitions from bright to dark. The sinusoidal variation provides a purer stimulus since there is a strong tendency for the turn-on in the square wave input to overshoot in luminance. This overshoot causes the modulation to be exaggerated, i.e., the peak luminance for high spatial frequencies becomes greater than would normally be caused by an input signal within the bandwidth limitations of the display. This overshoot easily can be interpreted during modulation transfer function analysis as an improved high frequency response when, in fact, it is an artifact of the display's response to the fast rise time stimulus and subsequent overshoot. This same result is not apparent when the turn-off portion of the square wave stimulus is analyzed.)

The combinations of the spatial and temporal frequencies presented in Table 3 are used. By convention, contrast measurements are not made for combinations beyond the point where the modulation contrast (M_c) dropped off to less than 5 percent (0.05).

Table 3.

Spatial and temporal frequencies

Spatial (Cycles/millimeters)	Temporal (Hertz)
0.2, 0.4, 0.6, 0.8, 1.0, 1.3, 1.7, 1.9, 2.1, 2.5, 3.8, 4.2, 5.0, 6.2, 7.5, 8.4, 9.4, 10.5	0, 1.875, 3.75, 5.0, 7.5, 10.0

The physical and electrical characteristics of the collection optics, PMT, and high voltage supply (which together function as a photometer) are critical to the interpretation of the measurements. A slit aperture is recommended. Its width should be approximately 10 times smaller than the highest spatial frequency measured in the object plane and its length should cover at least approximately 5 display scan lines. A 25 X 8000 micron width to length ratio is recommended. The objective lens power determines the effective width and length in the objective plane. A 5X microscope lens is used to give an effective 5 X 1600 micron measurement slit on the display screen. If the effective slit width is too large, the modulation amplitude measurements will be artificially low. If the slit width is too small, the luminance signal level will be low and noisy.

The radiometer and the photometric microscope with a 25 X 8000 micron slit are used to convert the spatial and temporal luminance values into an electrical signal which is measured using the digital storage oscilloscope. The radiometer is used only as a source of high voltage for the PMT. The output of the high frequency amplifier of the PMT is filtered by the two electronic filters before being fed to the oscilloscope. The filters, connected in series, act as a low pass filter with a cutoff frequency of 35 Hertz and provide 40 dB of gain. The temporal response of the photometer is very critical for the dynamic measurements. The limited range of response speeds typically encountered in off-the-shelf photometers is inadequate for reliable dynamic measurements. Therefore, the video or high frequency output of the photometer is required. The electronic filters provide amplification and filter out high frequency noise, improving the signal-to-noise ratio. The output of the filter is displayed on the digital oscilloscope.

For the dynamic measurements, a temporal frequency is selected and an input signal is applied to the display at each spatial frequency. For each spatial frequency, the photometer output signal is acquired using the storage oscilloscope. From the digitized waveform, the peak and trough values are obtained and used to calculate the modulation contrast value. This procedure is repeated for each temporal frequency.

3.1.3.2.20.5. Analytical method

Drifting sine wave technique: Modulation transfer ratios are calculated from the input and output modulation contrast data for all spatial and drift velocity combinations and plotted as a function of spatial frequency for each value of V. These curves are compared to the static MTF curve obtained in section 3.1.3.2.19.

Counterphase modulation technique: Modulation transfer ratios are calculated from the input and output modulation contrast data for all spatial and temporal frequency combinations and plotted as a function of spatial frequency for each value of temporal frequency. These curves are compared to the static MTF curve obtained in section 3.1.3.2.19.

3.1.3.2.21. Visor spectral transmittance

3.1.3.2.21.1. Objective

To determine the amount of radiant energy transmitted by Class I, II, and special visors as a function of wavelength.

3.1.3.2.21.2. Criteria

None, unless required by specification documents.

3.1.3.2.21.3. Apparatus

A spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and repeatability of ±1.0 percent, or equivalent. Special Class visors max require a spectral range which extends as low as 200 and/or as high as 1300 nm. A current regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength of the spectroradiometer is required.

3.1.3.2.21.4. Procedure

Spectroradiometric data are measured at normal incidence over the required wavelength range for a reference tungsten source alone and for the sample visor(s) and source combination.

3.1.3.2.21.5. Analytical method

The transmittance curves are obtained by performing a division, by wavelength, of the visor-source combination data by the source data. The measured spectral transmittance data are used for calculation of neutrality (paragraph 3.1.3.2.31.) and chromaticity (paragraph 3.1.3.2.32.) parameters.

3.1.3.2.22. Visor refractive power

3.1.3.2.22.1. Objective

To measure the difference in refractive power in and between the right and left optics of the visor(s).

3.1.3.2.22.2. Criteria

The spherical refractive power of the visor(s) at the center points and other selected points shall not exceed ±0.125 diopter. The cylindrical refractive power shall not exceed ±0.0625 diopter. (MIL-V-43511C)

Where required, additional or alternate criteria from specification documents shall be used.

Criteria for visors may be superseded by system refractive power criteria.

3.1.3.2.22.3. Apparatus

An automatic lensometer (Figure 25) or other method providing an accuracy of ±0.0625 diopters.

3.1.3.2.22.4. Procedure

The NFPD is positioned at points defined by a 65-millimeter interpupillary distance. Pressing the appropriate lensometer mode switch results in spherical and cylindrical power readings displayed in units of 0.01 diopter. Measurements are made perpendicular to the lens surface.

3.1.3.2.22.5. Analytical method

The measured refractive power values are compared to test criteria.

3.1.3.2.23. Visor prismatic deviation

3.1.3.2.23.1. Objective

To determine the prismatic power deviation between pairs of conjugate points on the visor(s).

3.1.3.2.23.2. Criteria

Vertical -- the algebraic difference between the vertical prismatic deviation of the center points (and other conjugate pairs) for the right and left eyes shall be no more than 0.18 diopter nor shall the vertical prism exceed 0.18 diopter at these points (MIL-V-43511C).

Horizontal -- the algebraic sum of the horizontal prismatic deviation of the center points (and other conjugate pairs) for the right and left eyes shall not exceed 0.50 diopter. The algebraic difference between the horizontal deviation at the center points shall not exceed 0.18 diopter (MIL-V-43511C).

Where required, additional or alternate criteria from specification documents shall be used for this test.

Criteria for visors may be superseded by system prismatic deviation criteria.

3.1.3.2.23.3. Apparatus

An automatic lensometer (Figure 25) or other method providing an accuracy of ±0.0625 prism diopters.

3.1.3.2.23.4. Procedure

Both vertical and horizontal prismatic power shall be measured at the left and right center points and at all other points of interest. Measurements are obtained with visors aligned (using test fixture) to replicate "as worn" position (Rash and Martin, 1986).

Base up prism shall be designated positive (+) and base down prism shall be designated negative (-). Base out prism (temporally deflected) shall be designated as positive (+) and base in prism (nasally deflected) shall be designated negative (-).

3.1.3.2.23.5. Analytical method

The vertical prismatic deviation values are determined by calculating the algebraic difference between the pairs of conjugate points. The horizontal prismatic deviation values are determined by calculating both algebraic sum and difference for the conjugate pairs. Comparisons of calculated values and criteria are made to determine compliance.

3.1.3.2.24. Visor haze

3.1.3.2.24.1. Objective

To determine the amount of light scattered by the visor(s) due to optical imperfections such as scratches, thickness variations, etc.

3.1.3.2.24.2. Criterion

The visors shall exhibit not more than 2 percent haze as cited in MIL-V-43511C. Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.24.3. Apparatus

Haze is measured using a Gardner* hazemeter, model XL-211 (Figure 26). This device assesses haze over an area of a circular area of 0.44 in^2.

3.1.3.2.24.4. Procedure

The procedure follows that of ASTM D1003-61 (1970), "Test for haze and luminous transmittance of transparent plastics." Following calibration with a reference haze glass sample, each visor sample is placed at the entrance port of the hazemeter's sensing unit. Measurements are taken at the center point of each lens for each sample. The haze value is read directly, in percent, from the hazemeter's display.

3.1.3.2.24.5. Analytical method

The measured haze values are compared to test criterion.

3.1.3.2.25. Visor distortion

3.1.3.2.25.1. Objective

To determine the level of magnification variation (distortion) in the visor(s).

3.1.3.2.25.2. Criterion

The visor, when used to view a test line grating, shall not produce objectionable levels of distortion.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.25.3. Apparatus

Distortion is evaluated using an Ann Arbor* optical tester (with a 50-line grating; Figure 27).

3.1.3.2.25.4. Procedure

The optical distortion is determined by inserting the device with its surface normal to the line-of-sight into the testing apparatus. Both the right and left optics of the visor(s) shall be tested. A scale of 0-5 is applied, where 0 represents no distortion and 5 equates to a totally unacceptable

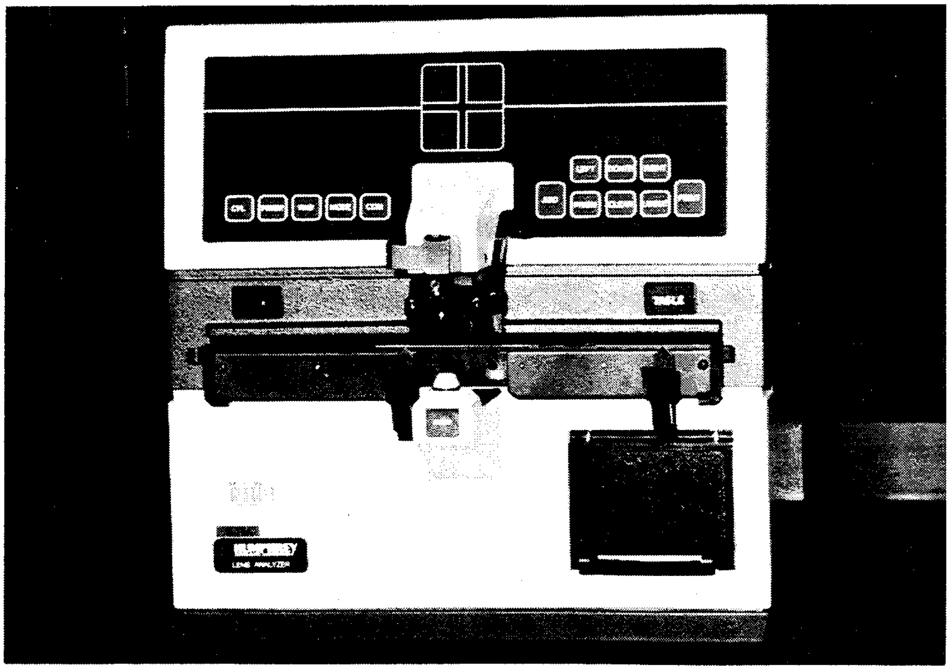


Figure 25. Automatic lensometer.

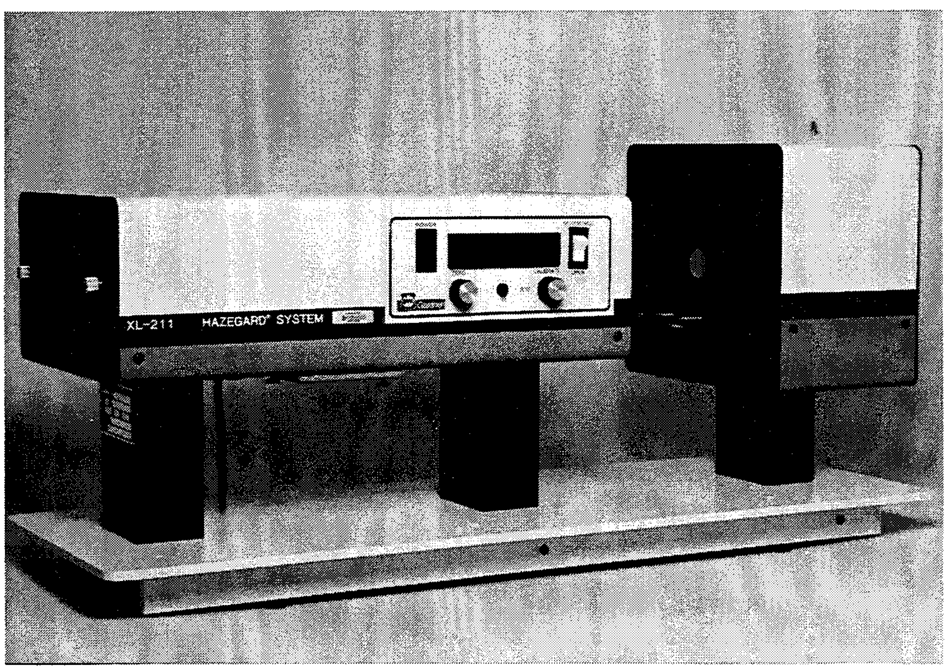


Figure 26. Hazemeter.

level of distortion. Two optical areas are evaluated: (1) the central portion of the right and left optics encompassing an area corresponding to 20 degrees about the optical center as subtended at the eye, and (2) the peripheral areas beyond the 20 degrees.

Measurements are made by viewing the zero distortion test pattern (Figure 28) through each sample visor and subjectively assigning a scale value to the viewed image.

3.1.3.2.25.5. Analytical method

Recorded values shall be compared to test criterion. Typically, distortion values of 3 or greater within the central optical area shall be reported as unacceptable. Values of 4 or greater in the peripheral area shall be reported as unacceptable.

3.1.3.2.26. Color discrimination with visor

3.1.3.2.26.1. Objective

To assess the user's ability to discriminate both saturated and desaturated colors when viewing through the visor(s). 3.1.3.2.26.2. Criteria

Class I (clear) and Class II (neutral tinted) visors shall not degrade color discrimination. Special Class (directed energy protective) visors shall produce minimum loss of color discrimination.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.26.3. Apparatus

The Farnsworth panel D-15 and Lanthony's desaturated 15-hue tests, or equivalent, are used (Rubin and Walls, 1972). Both tests consist of 16 color chips selected from the Munsell Book of Color. The hues (Munsell hue) are the same in the two tests and are selected so that the intervals between the different hues are approximately equal, but the purity (Munsell chroma) and luminosity level (Munsell value) are different. In the Farnsworth panel D-15 test, the mean chroma is approximately 4.2 and the mean value is approximately 5; in the Lanthony desaturated test the chroma is 2 and the value is 8. As a result, the color chips of the desaturated 15-hue test appear paler and lighter than those of the standard D-15 test.

The test materials consist of a rack, color caps, and scoring sheets. The rack is made of two hinged wooden panels. The color chips are mounted on the top of plastic caps with scoring numbers on the undersurface. A reference cap is fixed permanently to the left end of the bottom panel of the rack. The remaining 15 caps are placed in random order on the upper panel of the rack.

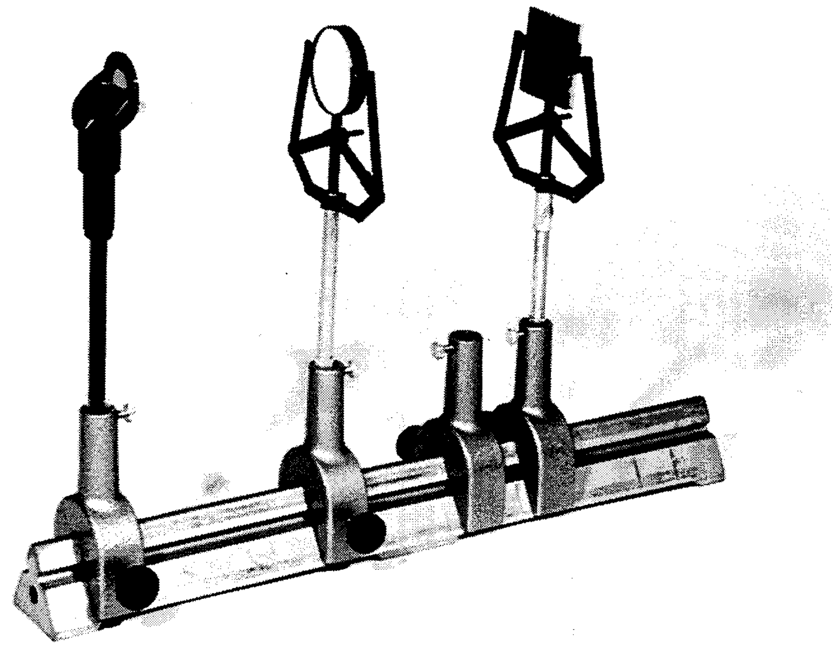


Figure 27. Optical distortion tester.

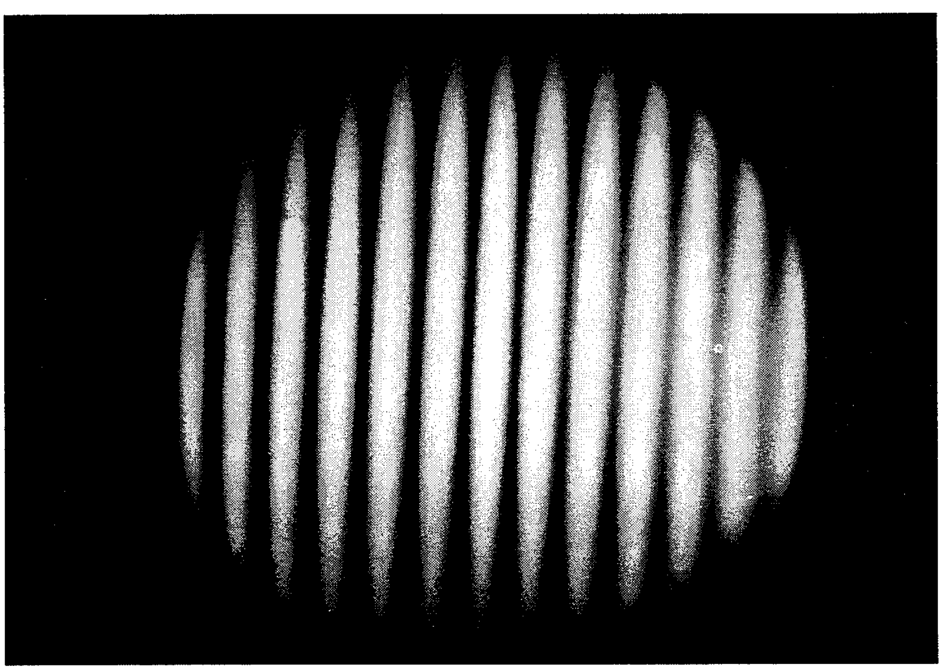


Figure 28. Zero distortion test pattern.

3.1.3.2.26.4. Procedure

The subject's task is to arrange the color chips (caps) in order according to color. The subject is instructed to first locate the color cap that most resembles the reference color cap and placing it next to it, then select the color cap that most resembles the last selected cap, etc., until all the caps are arranged in order. Subject's performance is recorded on the score sheet (Appendix 8).

A minimum of three subjects shall be evaluated for the conditions of naked eye and viewing through the visor(s).

3.1.3.2.26.5. Analytical method

A plot of the scores is made and compared with known examples of results obtained from both normal and color defective subjects. Although not specifically recommended for these tests, a quantitative scoring scheme designed for the Farnsworth FM-100 test is used to compare small differences in performance in normal observers on retesting with visor samples. The resulting error scores reflect the number of color caps misplaced and the distance that they are displaced from the correct positions.

3.1.3.2.27. Visor optical density (OD)

3.1.3.2.27.1. Objective

To determine the attenuation (expressed as optical density) of directed energy (laser) protective visors at identified wavelengths.

3.1.3.2.27.2. Criteria

Individual requirements for threat wavelengths are classified. The recommended value for common threat wavelengths is a minimum optical density of 4.0 at 532 nm, 694.3 nm, and 1064 nm. Any decrease in optical density in the visors resulting from the test exposure shall not exceed 0.5 for angles of incidence of 0 to 30 degrees from the normal for any polarization state of the incident laser radiation.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.27.3. Apparatus

Measurements are made using a Q-switched neodymium (Quantel model YG580, 23 nanosecond full width-half modulation) and ruby (Quantel model RB120, 80 nanosecond full width-half modulation) laser systems, and/or other laser sources as required to verify laser wavelengths of interest.

3.1.3.2.27.4. Procedure

Directed energy visors are tested for optical density using a test setup similar to that of Figure 29. (Also, see Figure 2, MIL-S-44366GL). A uniform beam of known area (minimum diameter of 12 mm) is produced on the sample. The exposure is normal to the test visor surface and incident from the convex side of the visor. A reference detector is used to normalize the laser output and measure the sample's incident energy. The transmission of the sample is determined by comparing it to the transmission of neutral density filters of known transmission. Measurements shall be performed at the optical centers of the test visor, as defined by line-of-sight, and at additional locations as deemed appropriate.

For Q-switched emissions of less than 40 nanoseconds and greater than 1 nanosecond, a radiant exposure of 20 millijoules per square centimeter is used.

3.1.3.2.27.5. Analytical method

The optical density (OD) of the sample is calculated using the relationship:

$$OD = \log_{10}(1/T)$$

where T is the measured transmission. Calculated values are compared to test criteria.

3.1.3.2.28. Visor abrasion resistance

3.1.3.2.28.1. Objective

To determine the resistance of the visors to scratching and abrasion.

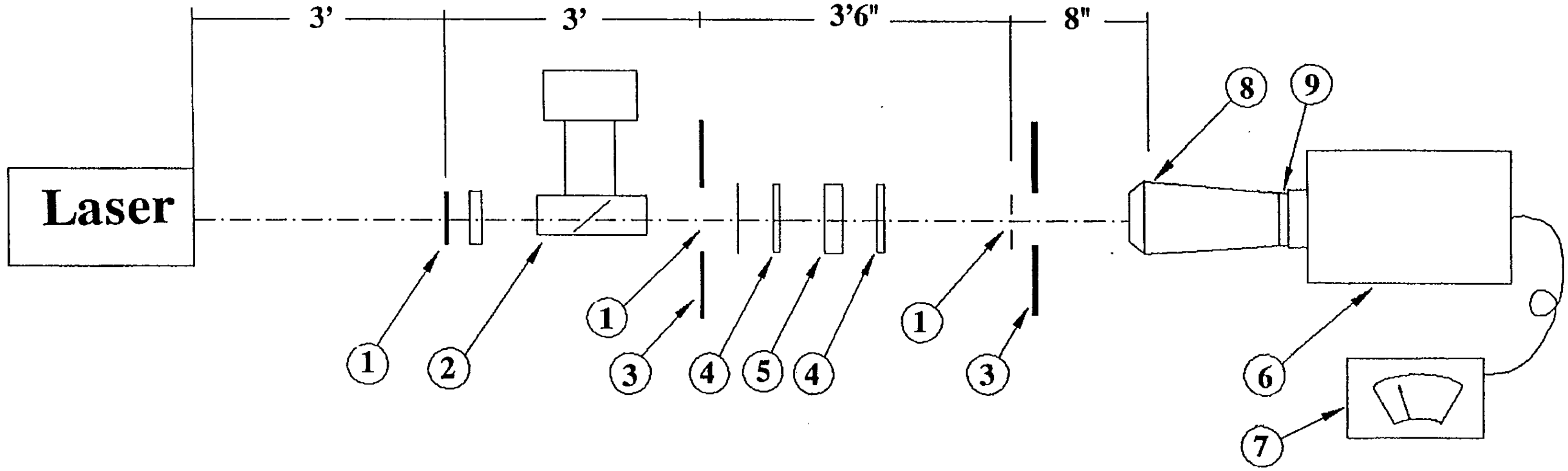
3.1.3.2.28.2. Criteria

After being subjected to the abrasion test, the increase in haze shall not exceed 6 percent and the decrease in luminous transmittance shall not exceed 4 percent.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.28.3. Apparatus

Test is performed using a spring loaded abrasion test assembly and standardized eraser as described in MIL-V-22272D(AS), "Visors, neodymium, protective for aircrewman's helmet." The eraser plug is defined in MIL-E-12397, "Eraser, rubber-pumice (for testing coated optical elements)."



1. Apertures
2. Beamsplitters and second radiometer
3. Baffles
4. Neutral density filters
5. Sample
6. Radiometer
7. Radiometer readout
8. Visible blocking filter
9. Hood and narrow band filter

Figure 29. Test setup for optical density of directed energy visors.

3.1.3.2.28.4. Procedure

Baseline haze and luminous transmittance measurements are performed on the visor samples in accordance with the procedures in paragraphs 3.1.3.2.24.4. and 3.1.3.2.29.4., respectively. The visors are then rubbed with the standardized eraser, held approximately normal to the visor. The eraser is rubbed across the surface of the visor from one point to another (approximately 1 inch apart), over the same path, for 20 complete cycles with a force of 2.0 to 2.5 pounds continuously applied. After the rubbing, the visor is cleaned using water and a mild soap solution and dried. Haze and luminous transmittance measurements are repeated for the tested area.

3.1.3.2.28.5. Analytical method

Haze and luminous transmittance measurements taken before and after abrasion testing are compared for compliance with test criteria.

3.1.3.2.29. Visor luminous transmittance

3.1.3.2.29.1. Objective

To determine the amount of visible light transmitted through the visor to the eye under photopic and scotopic conditions.

3.1.3.2.29.2. Criteria

MIL-V-43511C requires the photopic luminous transmittance of Class I (clear) visors to be not less than 85 percent. The photopic luminous transmittance of Class II (tinted, sun protective) visors must be between 12 and 18 percent at the center points and not vary more than 3 percent.

Further guidance from Natick Research, Development, and Engineering Center, Natick, Massachusetts, on laser (directed energy) protective visors for the SPH-4B aviator's helmet states the photopic luminous transmittance shall not be less than 40 percent for the "light" laser protective visor and not less than 10 percent for the "dark" laser protective visor (Appendix 9). This same guidance requires the scotopic transmittance to be not less than 40 percent for the "light" visor and not less than 9 percent for the "dark" laser visor. The terms "light" and "dark" are interpreted to mean "2-notch" and "3 (or greater)-notch," respectively.

In addition, recent unpublished work at USAARL has tentatively recommended a minimum transmittance of 30 percent during light levels consistent with dawn, dusk, and full moon.

Where required, additional or alternate criteria from specification documents shall be used for this test.

Criteria for visors may be superseded by system luminous transmittance criteria.

3.1.3.2.29.3. Apparatus

Luminous transmittance may be empirically calculated from spectral transmittance data obtained using a spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength region of interest also is used. Alternatively, a photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less, and photopic and scotopic filters may be used.

3.1.3.2.29.4. Procedure

If the luminous transmittance is to be calculated from spectral transmittance data, then the method described in paragraph 3.1.3.1.2.4. is used to acquire the spectral data. These data then are weighted using the spectral weighting factors for photopic and scotopic relative spectral luminous efficiency given in Appendix 5. (Kingslake, 1965; American Institute of Physics Handbook, 1962).

When using the photometer, luminance measurements are taken at the center points of the right and left optics as defined by the lines of sight in the "as worn" position. Each measurement consists of reading the luminance of the reference lamp, placing the visor normal to the optical path, and taking a second luminance reading. The transmittance is calculated by dividing the luminance value obtained without the visor in place into the value obtained when the visor is in place. Measurements are obtained using the photometer's photopic and scotopic settings.

3.1.3.2.29.5. Analytical method

Transmittance values for Class I and II visors are compared to test criteria. Due to the nature of selectively filtered directed energy protective visors and special requirements of other Special Class visors, the analysis of their transmittance values are case dependent.

3.1.3.2.30. Visor ultraviolet transmittance

3.1.3.2.30.1. Objective

To measure the ultraviolet transmittance of the visor(s).

3.1.3.2.30.2. Criterion

The average ultraviolet transmittance shall not be more than 1 percent (MIL-V-43511C).

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.30.3. Apparatus

Ciba Corning response series ultraviolet-visible spectrophotometer or spectroradiometer which has a spectral range which contains the wavelengths if 250 to 320 nm, inclusive.

3.1.3.2.30.4. Procedure

Calibration is performed initially with the test cell empty. After placement of sample in test cell, the spectrophotometer performs an automatic scan of sample and produces a printed output of transmittance data.

If a spectroradiometer is used, the procedure for acquiring the spectral data is the same as described in paragraph 3.1.3.1.2.4. for spectral transmittance. The tungsten source is then replaced with a suitable source of ultraviolet energy.

3.1.3.2.30.5. Analytical method

The transmittance is computed as the average spectral transmittance at wavelengths of 250, 270, 290, 300, 310, and 320 nm. This value is compared to test criterion.

3.1.3.2.31. Visor neutrality

3.1.3.2.31.1. Objective

To verify a uniform distribution of transmitted energy throughout the visible spectrum (430-730 nm) to minimize color distortion.

3.1.3.2.31.2. Criterion

Neutrality is verified only for Class II (tinted, sun protective) visors. The spectral transmittance may vary with wavelength between 430 and 730 nm. The calculated spectral transmittance deviation (neutrality value) shall be less than 12 percent (MIL-V-43511C).

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.31.3. Apparatus

Measurement shall be performed using a spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength region of interest also is used.

3.1.3.2.31.4. Procedure

Spectral data are acquired using the procedure in paragraph 3.1.3.1.2.4. for spectral transmittance.

3.1.3.2.31.5. Analytical method

The neutrality is calculated by the Judd Daylight Duplication Method. This method requires calculating the average spectral transmittance deviation for 9 spectral bands between 430 and 730. (See paragraph 4.5.8. of MIL-V-43511C.)

3.1.3.2.32. Visor chromaticity

3.1.3.2.32.1. Objective

To determine the chromaticity coordinates of the visor(s).

3.1.3.2.32.2. Criterion

Chromaticity is calculated for Class II (tinted, sun protective) and Special Class visors. The 1931 Commission Internationale de l'Eclairage (CIE) chromaticity coordinates x and y shall be within the limits indicated in Figure 8. (Wyszecki and Stiles, 1967).

Where required, additional or alternate criteria from specification documents shall be used for this test.

Criteria for visors may be superseded by system chromaticity criteria.

3.1.3.2.32.3. Apparatus

Measurement shall be performed using a spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength region of interest also is used.

3.1.3.2.32.4. Procedure

Spectral data are acquired using the procedure in paragraph 3.1.3.1.2.4. for spectral transmittance.

3.1.3.2.32.5. Analytical method

The chromaticity coordinates x and y are calculated from the spectral transmittance data by the method presented in MIL-V-43511C, paragraph 4.5.9.

3.1.3.2.33. Visor visual (cosmetic) defects

3.1.3.2.33.1. Objective

To determine the presence and frequency of visual defects, e.g., scratches, blemishes, sharp edges, cracks, etc., in the visor(s).

3.1.3.2.33.2. Criteria

MIL-V-43511C establishes criteria for visor visual defects based on classification of these defects as critical, major, or minor (MIL-V-43511C, Table I, page 7). No critical defects are allowed. The number of major defects shall not exceed 2.5 per hundred visors and the sum of the major and minor defects shall not exceed 4.0 per hundred visors.

Additional criteria have been developed in support of the IHADSS program. IHADSS specification ES33830-01 defines the level of the optical defects to be applied in the inspection of IHADSS visors. These criteria involve a classification of defects as gross flaws or blemishes with further description of spatial frequency as to a single defect or a cluster of defects.

Under the IHADSS criteria, no gross flaws (single or cluster) are allowed in the critical viewing area and no more than five blemishes are allowed in the critical viewing area.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.33.3. Apparatus

A uniform background fluorescent light source and a measuring device with 0.01 inches minimum resolution are used. The alternative procedure requires two 15-watt fluorescent tubes and a black matte background.

3.1.3.2.33.4. Procedure

Using the naked eye at a viewing distance of 10-14 inches, each visor is visually inspected for the presences of any pit, dig, scratch, bubble inclusion, blister, crack, hole, chip, break, cloudiness, abrasion, striae, stain, discoloration, burr, or other visible defect. Each defect is recorded with respect to type, size (length and width or diameter), and location (critical, non-critical, or outside area of vision).

In an alternative procedure, cited in MIL-C-48497A, Coating, single or multilayer interference: Durability requirements for, any visor coating is visually examined by reflection, with the unaided eye, for evidence of flaking, peeling, cracking, or blistering. The inspection is performed using two 15-watt fluorescent light tubes as the light source. The viewing distance from the visor to the eye is less than 18 inches. The visors are viewed against a black matte background. The test setup is depicted in Figure 30.

3.1.3.2.33.5. Analytical method

If MIL-V-43511C criteria are used, then each defect is classified as critical, major, or minor by the definitions in MIL-V-43511C, page 7, Table I. The number of critical, major, and sum of major and minor defects are compared to the criteria.

If the IHADSS criteria are used, the identified defects are classified according to the following definitions:

Gross flaw - Any pit, scratch, dig, bubble, inclusion, etc., which exceeds 0.034 inches in diameter or 0.100 inches long by 0.010 inches wide.

Blemish - Any pit, scratch, dig, bubble, inclusion, etc., which is equal to or less than 0.034 inches in diameter or 0.100 inches long by 0.010 inches wide and no less than 0.015 inches in diameter.

Cluster - Three or more blemishes within a 0.50 inch diameter zone.

The number of each class of defect is compared to the criteria.

3.1.3.2.34. Nuclear flashblindness protective device open state luminous transmittance

3.1.3.2.34.1. Objective

To determine the amount of visible light transmitted through the nuclear flashblindness protective device (NFPD) to the eye under photopic and scotopic conditions in the open state. This test assumes nuclear flashblindness protection is provided by an individual subsystem/component and is not integral to the display optics.

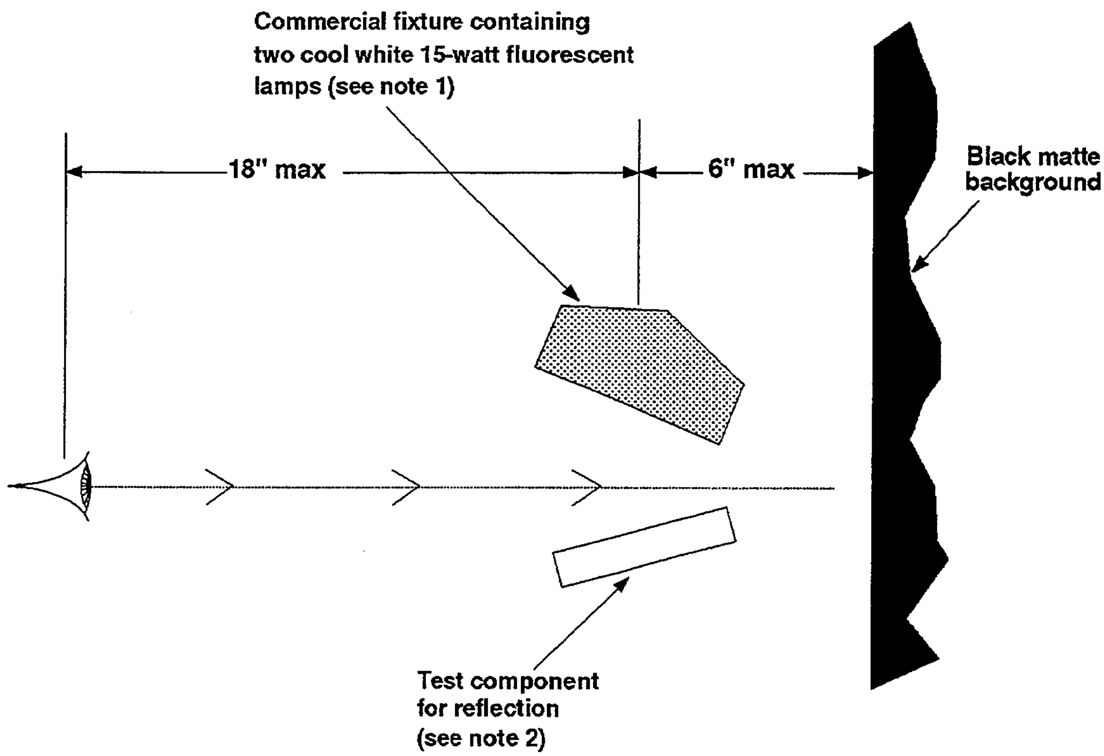


Figure 30. Alternative test setup for inspection for visor visual defects.

3.1.3.2.34.2. Criteria

As required by specification documents. A minimum of 30 percent photopic luminous transmittance has been recommended for night use. Criteria for the nuclear flashblindness protective device may be superseded by system luminous transmittance criteria.

3.1.3.2.34.3. Apparatus

Luminous transmittance may be empirically calculated from spectral transmittance data obtained using a spectroradiometer having a bandwidth of 10 nanometers (nm) or less, a minimum spectral range of 380 to 730 nm, a minimum wavelength accuracy of ±1.0 nm, and a repeatability of ±5.0 percent, or equivalent. A regulated reference tungsten source (correlated color temperature of 2557°K) providing energy over the full wavelength region of interest also is used. Alternatively, a photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less, and photopic and scotopic filters may be used. A power supply to activate the nuclear flashblindness protective device may be required.

3.1.3.2.34.4. Procedure

If the luminous transmittance is to be calculated from spectral transmittance data, then the method described in paragraph 3.1.3.1.2.4. is used. These data then are weighted using the spectral weighting factors for photopic and scotopic relative spectral luminous efficiency given in Appendix 5. (Kingslake, 1965; American Institute of Physics Handbook, 1962).

When using the photometer, luminance measurements are taken at the center points of the right and left optics, as defined by the lines of sight in the "as worn" position. Each measurement consists of reading the luminance of the reference lamp, placing the test device normal to the optical path, and taking a second luminance reading. The transmittance is calculated by dividing the luminance value obtained without the visor in place into the value obtained when the visor is in place. Measurements are obtained using the photometer's photopic and scotopic settings.

3.1.3.2.34.5. Analytical method

Measured values are compared to the test criteria.

3.1.3.2.35. Nuclear flashblindness protective device optical distortion

3.1.3.2.35.1. Objective

To determine the level of magnification variation (distortion) in the nuclear flashblindness protective device.

3.1.3.2.35.2. Criterion

The NFPD's lenses, when used to view the test line grating, shall not produce "objectionable" levels of distortion.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.3.2.35.3. Apparatus

Testing is performed using an Ann Arbor optical tester (with a 50-line grating).

3.1.3.2.35.4. Procedure

The optical distortion is determined by inserting the device with its surface normal to the line-of-sight into the testing apparatus. Both the right and left lens of the NFPD shall be tested. A scale of 0-5 is applied, where 0 represents no distortion and 5 equates to a totally unacceptable level of distortion. Two optical areas are evaluated: (1) the central portion of each lens encompassing an

area corresponding to 20 degrees about the optical center as subtended at the eye, and (2) the peripheral area beyond the 20 degrees.

Measurements are made by viewing the zero distortion test pattern (Figure 28) through each sample device and subjectively assigning a scale value to the viewed image.

Local optical defects detected during distortion evaluation also shall be recorded.

3.1.3.2.35.5. Analytical method

Recorded values shall be compared to test criterion. Typically, distortion values of 3 or greater within the central optical area shall be reported as unacceptable. Values of 4 or greater in the peripheral area shall be reported as unacceptable.

3.1.3.2.36. Nuclear flashblindness protective device prismatic deviation

3.1.3.2.36.1. Objective

To determine the prismatic power deviation between pairs of conjugate points of the NFPD.

3.1.3.2.36.2. Criteria

Vertical -- the algebraic difference between the vertical prismatic deviation of the center points (and other conjugate pairs) for the right and left eyes shall be no more than 0.18 diopter nor shall the vertical prism exceed 0.18 diopter at these points (MIL-V-43511C).

Horizontal -- the algebraic sum of the horizontal prismatic deviation of the center points (and other conjugate pairs) for the right and left eyes shall not exceed 0.50 diopter. The algebraic difference between the horizontal deviation at the center points shall not exceed 0.18 diopter (MIL-V-43511C).

Where required, additional or alternate criteria from specification documents shall be used for this test.

Criteria for the NFPD may be superseded by system prismatic deviation criteria.

3.1.3.2.36.3. Apparatus

An automatic lensometer (Figure 25) or other method providing an accuracy of ±0.0625 prism diopters.

3.1.3.2.36.4. Procedure

Both vertical and horizontal prismatic power shall be measured at the left and right center points and at all other points of interest. Measurements are obtained with NFPD aligned (using test fixture) to replicate "as worn" position (Rash and Martin, 1986).

Base up prism shall be designated positive (+) and base down prism shall be designated negative (-). Base out prism (temporally deflected) shall be designated as positive (+) and base in prism (nasally deflected) shall be designated negative (-).

3.1.3.2.36.5. Analytical method

The vertical prismatic deviation values are determined by calculating the algebraic difference between the pairs of conjugate points. The horizontal prismatic deviation values are determined by calculating both algebraic sum and difference for the conjugate pairs. Comparisons of calculated values and test criteria are made to determine compliance.

3.1.3.2.37. Nuclear flashblindness protective device refractive power

3.1.3.2.37.1. Objective

To measure the difference in refractive power in and between the right and left optics of the NFPD.

3.1.3.2.37.2. Criteria

The spherical refractive power of the NFPD device at the center points and other selected points shall not exceed ±0.125 diopter. The cylindrical refractive power shall not exceed ±0.0625 diopter.

Where required, additional or alternate criteria from specification documents shall be used for this test.

Criteria for NFPD may be superseded by system refractive power criteria.

3.1.3.2.37.3. Apparatus

An automatic lensometer (Figure 25) or other method providing an accuracy of ±0.0625 diopters.

3.1.3.2.37.4. Procedure

The samples are positioned at points defined by a 65-millimeter interpupillary distance. Pressing the appropriate mode switch results in spherical and cylindrical power readings displayed in units of 0.01 diopter. Measurements are made perpendicular to the lens surface.

3.1.3.2.37.5. Analytical method

The measured refractive power values are compared to test requirements.

3.1.3.2.38. Nuclear flashblindness protective device closed state optical density

3.1.3.2.38.1. Objective

To determine the amount of visible light transmitted through the nuclear flashblindness protective device to the eye under photopic conditions in the closed state. This test assumes nuclear flashblindness protection is provided by an individual subsystem/component and is not integral to the display optics.

3.1.3.2.38.2. Criterion

As required by specification documents. A minimum optical density of 3.5 is recommended.

3.1.3.2.38.3. Apparatus

To perform the closed state measurement, a high luminance source in excess of 10,000 footlamberts is required. Measurements are made with a photometer having an accuracy of ±2 percent, a full scale sensitivity of 1.0 footlambert or less. A power supply to activate the nuclear flashblindness protective device may be required.

3.1.3.2.38.4. Procedure

A high luminance source (10,000 footlamberts or greater) is used as a reference source. Luminance measurements are taken at the center points of the right and left optics, as defined by the lines of sight in the "as worn" position. Each measurement consists of reading the luminance of the reference lamp, placing the test device normal to the optical path, and taking a second luminance reading. The transmittance is calculated by dividing the luminance value obtained without the visor in place into the value obtained when the device is in place. Measurements are obtained using the photometer's photopic settings. Note: In devices using cross polarization, a luminance pattern (Maltese Cross) may be present in the closed state (McLean and Rash, 1985). In these devices luminous transmittance shall be measured at the most luminous section of the pattern.

3.1.3.2.38.5. Analytical method

Measured values are compared to test criteria.

3.1.4. Biodynamic

Biodynamic testing is applicable to the IHDS as a total system and to the protective helmet and head tracking/aiming subsystems. The biodynamic system and subsystem/component test parameters are presented in Table 4.

Table 4.

Biodynamic test parameters

Test	Section
System	
Mass properties	3.1.4.1.1.
Impact attenuation	3.1.4.1.2.
Stability	3.1.4.1.3.
Dynamic retention	3.1.4.1.4.
Anthropometric fit/comfort	3.1.4.1.5.
Ballistic protection	3.1.4.1.6.
HMD breakaway force	3.1.4.1.7.
Protective helmet	
Shell tear resistance	3.1.4.2.1.
Chinstrap assembly integrity	3.1.4.2.2.
Head tracker/aiming system	
Motion box size	3.1.4.2.3.
Update rate	3.1.4.2.4.
Jitter	3.1.4.2.5.
Pointing angle accuracy	3.1.4.2.6.
Pointing angle resolution	3.1.4.2.7.

3.1.4.1. System tests

The following tests are applicable to the total system. A specific test may be performed for multiple system configurations. In the destructive tests, non-functional electro-optical components may be substituted for functional components. However, the mass, center-of-mass (CM), dimensional, and material properties of the non-functional components shall represent operational

components. Weight equivalent dummy cables that are severed within 30 cm from the exit of the shell shall be substituted for operational cables, i.e. communications, power supply, fiber optics, etc., for the mass property evaluations.

3.1.4.1.1. Mass properties

3.1.4.1.1.1. Objective

To analytically measure the IHDS head supported mass and its respective center-of-mass (CM) location for each IHDS configuration. The reference coordinate system for the CM measurements shall be the head anatomical coordinate system shown in Figure 31.

3.1.4.1.1.2. Criteria

The allowable IHDS mass is interrelated to the X- and Z-axis CM locations as shown in Figures 32 and 33. When the Z-axis CM value is plotted against the recorded mass on Figure 32, this point shall lie to the left and below the constant moment curve and maximum allowable mass and CM limits. When the X-axis CM value is plotted against the recorded mass on Figure 33, this point shall lie in the acceptable region, below the constant moment curve. The Y-axis CM location shall lie within 19 mm of the midsagittal (XZ) plane.

3.1.4.1.1.2.1. Mass

The maximum allowable mass, regardless of CM values, is 2.5 kg for helicopter cockpits without airbags and 3.0 kg for helicopter cockpits with airbags.

3.1.4.1.1.2.2. Center-of-mass (CM)

The maximum Z-axis CM value, regardless of the IHDS mass, is 52 mm. The Z-axis constant moment curve is defined by the equation: vertical CM = {(298/mass)-119.4}. The X-axis constant moment curve is defined by the equation: longitudinal CM = {(108.05/mass)-20.0}, but shall be no less than -20 millimeters. The Y-axis CM value shall lie within 19 mm of the midsagittal plane. These requirements do not represent user acceptability, aircrew performance, fatigue or long term health effects.

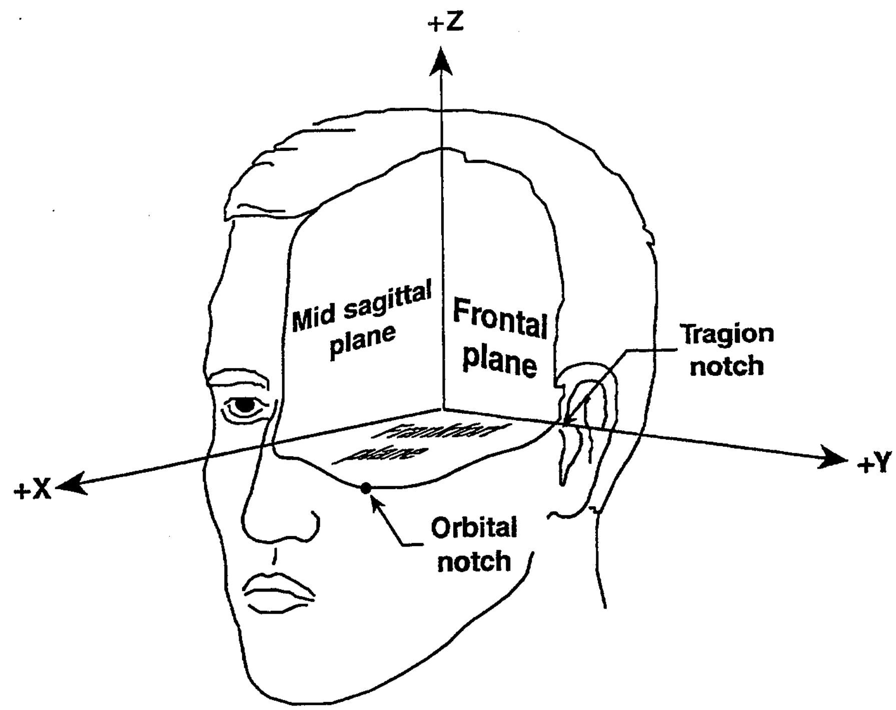


Figure 31. Head anatomical coordinate system.

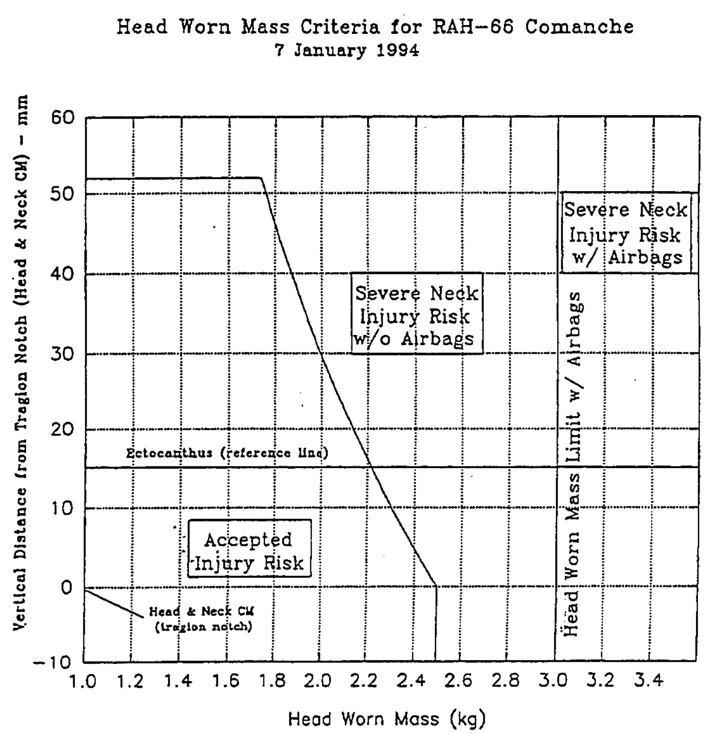


Figure 32. Head worn mass criteria, z-axis, constant moment curve.

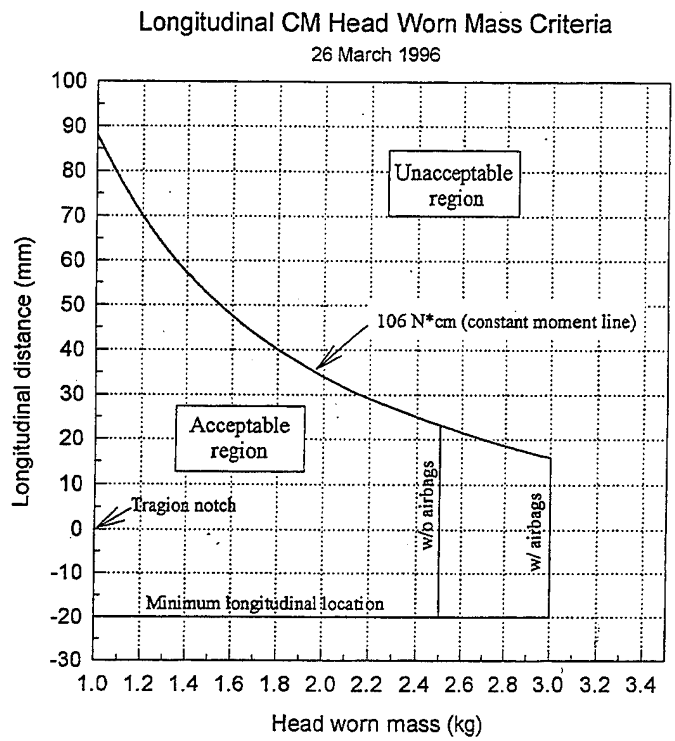


Figure 33. Head worn mass criteria, radial distance, Frankfort plane.

3.1.4.1.1.3. Apparatus

3.1.4.1.1.3.1. Mass

A calibrated digital scale capable of measurement to the nearest 1.0 gram with a resolution of 0.1 gram shall be used when measuring the IHDS system weight.

3.1.4.1.1.3.2. Center-of-mass (CM)

The test device used to determine the IHDS CM shall have an accuracy of 1.0 mm and a resolution of 0.5 mm. A 50th percentile male headform as defined in Anthropometry and mass distribution for human analogues, volume I: Military male aviators (USAARL Report No. 88-5) shall be mounted on this device for positioning of the IHDS. The test device shall be as described in An automated method for determining mass properties (USAARL Report No. 93-4), or equivalent.

3.1.4.1.1.4. Procedure

These procedures shall be performed for each IHDS configuration.

3.1.4.1.1.4.1. Mass

Each IHDS configuration shall be placed on the digital scale and weighed. The IHDS configurations and their masses shall be recorded.

3.1.4.1.1.4.2. Center-of-mass (CM)

The IHDS shall be fitted to the test headform in accordance with the fitting procedures specified by the IHDS contractor. Care shall be taken to ensure the helmet standoff distance is within the design tolerance and that the IHDS optical components are appropriately located relative to the headform's eye position. For each axis, a minimum of three CM determinations shall be recorded and averaged. Between each determination, the IHDS shall be removed and repositioned onto the headform to normalize the variability within IHDS fitting and positioning.

3.1.4.1.1.5. Analytical method

For each IHDS configuration, the recorded mass shall be plotted against its Z-axis and X-axis CM location on Figures 32 and 33, respectively. A direct comparison shall be made of the measured Y-axis CM values against the maximum allowed Y-axis CM position.

3.1.4.1.2. Impact attenuation

3.1.4.1.2.1. Objective

To measure the deceleration levels of a magnesium headform when it is fitted with a complete IHDS and impacted against a flat anvil at a given impact velocity. A total of seven impacts shall be conducted on the IHDS in its most hazardous configuration.

3.1.4.1.2.2. Criteria

The peak acceleration for each impact shall not exceed the maximum G-force thresholds for the impact locations and velocities given in Table 5.

3.1.4.1.2.3. Apparatus

The impact tests shall be performed on a guided, free fall drop tower conforming to ANSI Z90.1-1992. The headform shall be the magnesium size C (medium) headform modified in the earcup region to allow lateral impact testing of the IHDS. These modifications are shown in Figure 34. The total weight of the headform and drop arm assembly shall be 5 kg with an allowable tolerance of +0.09 and -0 kg (11 lb, +0.2 and -0 lb).

Table 5.

Impact attenuation maximum G thresholds

Impact location	Impact velocity (m/s) Minimum	Maximum	Drop height (meters)	Maximum G*
Crown	4.88	4.95	1.22	150
Left earcup	5.98	6.05	1.83	150
Right earcup	5.98	6.05	1.83	150
Front	5.98	6.05	1.83	175
Rear	5.98	6.05	1.83	175
Left side	5.98	6.05	1.83	175
Right side	5.98	6.05	1.83	175

* High speed photography shall be used to verify electro-optical component displacement do not constitute a hazard to the face and head.

3.1.4.1.2.4. Procedure

The IHDS shall be fitted to the test headform in accordance with the provided fitting procedures. Care shall be taken to ensure the proper helmet and optical positions are maintained relative to the eye reference plane of the headform. The headform/IHDS assembly is then raised to a height sufficient to achieve the desired impact velocity. The headform deceleration during impact is measured and recorded electronically as an acceleration versus time trace.

The impact velocity shall be measured just prior to impact. Impact locations are defined by positioning the headform in accordance with Figure 35. A flat anvil shall be used for all impacts. Each impact location shall be subjected to a single impact only. The IHDS shall be a complete assembly. Non-functional electro-optic components may be substituted for functional components, but must retain the mechanical properties (dimensions, materials, weight, strength, yield points, etc.) of a functional system.

3.1.4.1.2.5. Analytical method

The recorded peak G for each impact shall be compared to the corresponding limit for the impact location. Any result which exceeds the requirement constitutes a failure except in cases where the impact velocity exceeds the maximum specified. In this case the test shall be considered invalid and be repeated. Tests where the minimum impact velocity is not attained shall also be considered invalid and repeated.

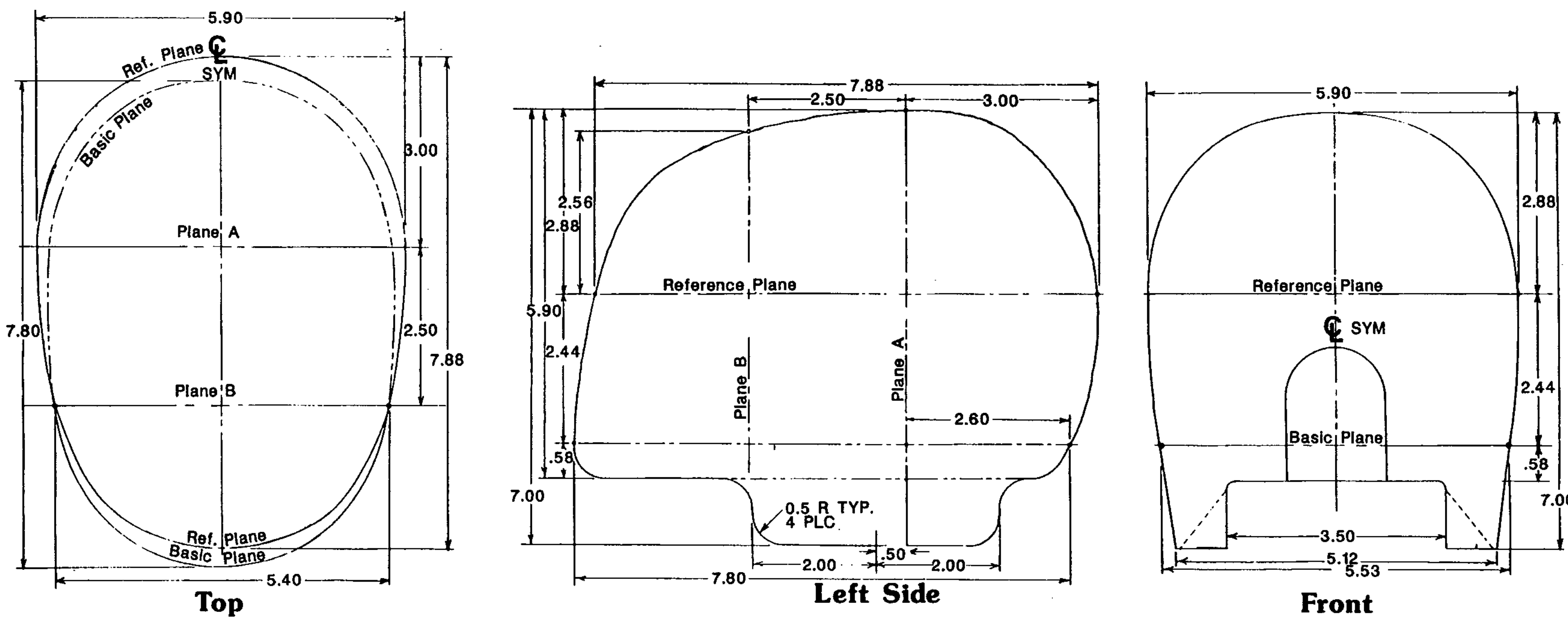


Figure 34. ANSI Z-90.1 magnesium, size C (medium) headform modified in the earcup region to allow lateral impact testing.

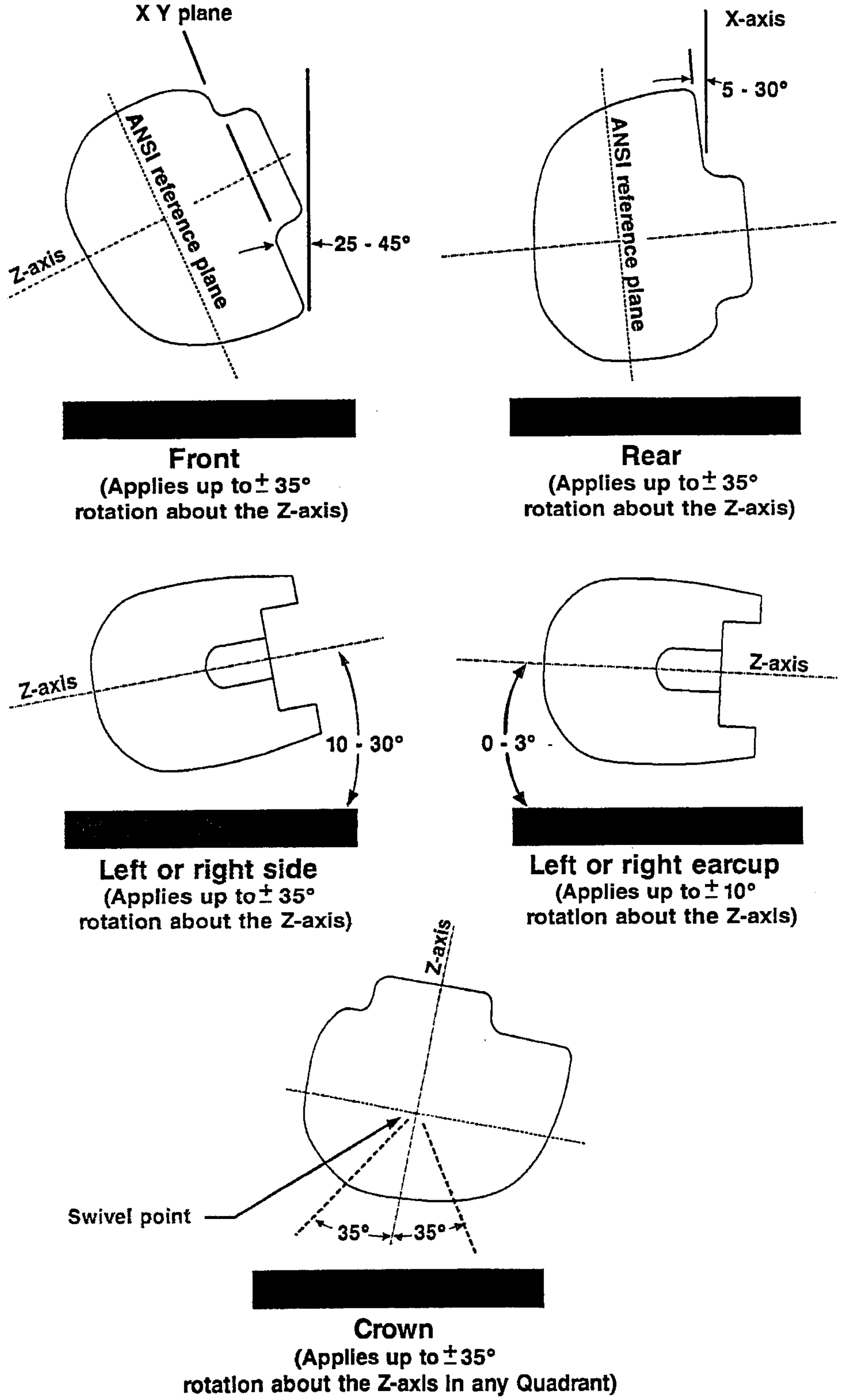


Figure 35. Impact test locations.

3.1.4.1.3. Stability

3.1.4.1.3.1. Objective

To measure IHDS stability when subjected to various quasi static torque loadings and vectors. These range from low level in-flight rotational loadings (6.0 Newton-meter) to high level crash rotational loadings (60.0 Newton-meter) applied about the head anatomical origin defined by Figure 31. The IHDS shall be evaluated in its most hazardous configuration.

3.1.4.1.3.2. Criteria

3.1.4.1.3.2.1. Angular displacement

The angular displacement recorded during the 6.0 Newton-meter torque shall not exceed the IHDS angular displacement which results in a 10 percent image loss. The angular displacement recorded during the 60.0 Newton-meter torque shall not exceed the maximum allowable rotation cited by the system specification.

3.1.4.1.3.2.2. Facial contact

The angular displacement resulting from the applied torques shall not result in the optical system, supporting surfaces, or frames to contact the facial, eye, or forehead regions of the headform.

3.1.4.1.3.3. Apparatus

A 50th percentile headform, as defined by USAARL Report No. 88-5 (Anthropometry and mass distribution for human analogues, Volume I: Military male aviators, 1988) shall be used for the low and high level torque loadings. Additionally, human subjects may be utilized in the low level tests. An inclinometer shall be noninvasively mounted onto the IHDS to measure angular displacement. A force gage shall be used to monitor the force applied to the IHDS.

3.1.4.1.3.4. Procedure

A thin layer (approximately 2 mm thick) of pliable clay shall cover the facial, eye, and forehead regions of the headform for positive indication of contact with electro-optic components. The IHDS shall be fitted to the test headform in accordance with the fitting procedures provided by the IHDS contractor. Care shall be exercised in maintaining the proper helmet and electro-optic positions relative to the headform's eye reference plane. Human subjects may be used in addition to the headform during the low level tests. Chinstrap tension shall be measured and adjusted to a constant setting, to simulate a snug "as worn" condition, before each test.

The desired torque values, 6 and 60 Newton-meters, shall be used to determine the load required depending on its point of application. The distance is determined from the orthogonal axes of the head anatomical coordinate system shown in Figure 31. The loads creating the torques may vary depending on the distance from the headform origin to the point of load application.

For all load levels, the load shall be applied tangent to the IHDS shell. The load shall be applied separately to the front edge, rear nape edge, and left and right sides of the IHDS shell.

The load shall be gradually applied to the IHDS until the required load is obtained. This load shall be held constant for a minimum of 30 seconds or until IHDS movement has ceased. A final reading shall then be made and the load removed. The absolute difference between the initial and final reading is the angular rotation of the IHDS. At completion of each evaluation, an inspection of the headform's clay witness areas shall be conducted. Any contact of the electro-optical components with the headform's facial, eye, or forehead regions shall be documented and photographed. For each loading direction, a minimum of three tests shall be performed and the inclinometer readings averaged. Between each test, the IHDS shall be removed and repositioned onto the headform to normalize the variability within IHDS fitting and positioning.

3.1.4.1.3.5. Analytical method

The average angular rotation shall be calculated for each torque loading condition and compared to the test criteria.

3.1.4.1.4. Dynamic retention

3.1.4.1.4.1. Objective

To comparatively evaluate the IHDS retention characteristics against an SPH-4B and HGU-56/P helmet when subjected to a simulated crash pulse.

3.1.4.1.4.2. Criteria

3.1.4.1.2.1. Helmet rotation

The IHDS helmet's angular displacement, relative to the test headform, shall be measured and compared against the SPH-4B and HGU-56/P helmets system to ensure helmet retention is not compromised.

3.1.4.1.2.2. Facial contact

The angular displacement resulting from the simulated crash pulse shall not result in the optical system, supporting surfaces, or frames to contact the facial, eye, or forehead regions of the headform.

3.1.4.1.4.3. Apparatus

A pendulum test device with a Hybrid II head and Hybrid III neck installed shall be utilized to conduct this evaluation. The pendulum test device is described in USAARL LR 88-5-4-3, Development of a test method for evaluating the effectiveness of helmet retention systems.

3.1.4.1.4.4. Procedure

A thin layer (approximately 2 mm thick) of pliable clay shall cover the forehead, eye socket, and facial regions of the headform for positive indication of contact with electro-optic components. The IHDS shall be fitted to the Hybrid II headform in accordance with the procedures specified by the IHDS contractor. Care shall be taken to ensure the proper helmet position and electro-optic adjustments are maintained before each test. An SPH-4B and HGU-56/P shall be evaluated along with the IHDS to minimize variabilities from previous evaluations.

Testing shall be conducted in accordance with USAARL LR 88-5-4-3, Development of a test method for evaluating the effectiveness of helmet retention systems. Any contact of the electro-optical components with the headform shall be documented and photographed.

3.1.4.1.4.5. Analytical method

The IHDS helmet angular displacement, relative to the test headform, shall be compared against the SPH-4B and HGU-56/P Army aviator helmets.

3.1.4.1.5. Anthropometric fit/comfort

3.1.4.1.5.1. Objective

To subjectively evaluate the adequacy of the IHDS fitting system by rated aviators in a flight simulator.

3.1.4.1.5.2. Criteria

The IHDS shall be capable of accommodating the 5th through the 95th percentile Army male aviator head dimensions. The IHDS shall be capable of being worn by rated aviators during a continuous 3 hour flight simulation period without removal of the IHDS for relief from irritations, headaches, or pressure points (hot spots). The frequency of in-flight IHDS adjustments during this simulation period shall not exceed two adjustments per hour.

3.1.4.1.5.3. Apparatus

Standard anthropometric measurement instruments shall be used during the anthropometric measurements of test subjects. These data are recorded for each subject. A UH-60 flight simulator

shall be utilized in this evaluation. The UH-60 flight simulator's cockpit shall be environmentally conditioned to 26 degrees Celsius and 75 percent relative humidity.

3.1.4.1.5.4. Procedure

Test subjects shall have the following anthropometric parameters measured prior to being fitted with the IHDS. These measurements are identified in NATICK TR-91/040, 1988 Anthropometry survey of U.S. Army personnel: pilot summary statistics, and USAARL Report No. 88-5, Anthropometry and mass distribution for human analogues, volume I: Military male aviators.

1. ectocanthus - back of head
2. ectocanthus - top of head
3. glabella - back of head
4. head breadth
5. head circumference
6. head length
7. interpupillary breadth
8. tragion - top of head
9. tragion - back of head.

The IHDS configuration used in this evaluation shall be the full display configuration. For each IHDS size, a minimum of six test subjects, having anthropometric dimensions within the sizing ranges specified by the IHDS contractor, shall be selected for this evaluation. Each subject shall be fitted with the IHDS in accordance with the fitting procedures provided by the IHDS contractor. Any difficulties in obtaining an appropriate helmet fit or acceptable display positioning shall be documented. Once an acceptable fit is obtained, the subject shall be instructed on the proper donning, doffing, and in-flight adjustment procedures of the IHDS. The subject then shall wear the IHDS continuously for a minimum of 3 hours in a UH-60 flight simulator. During the flight simulation, the test subject shall be monitored to record the number of adjustments made by the test subject (i.e., supporting the helmet, loosening or tightening adjustment straps, removing or lifting the IHDS or any component, etc.). After completion of the flight simulation, the test subject shall complete a subjective questionnaire on the IHDS fitting, comfort, stability, and ease of use Appendix 10).

3.1.4.1.5.5. Analytical method

For anthropometric fit, the recorded anthropometric measurements from both the successful and unsuccessful subject fittings shall be evaluated against the recommended sizing criteria provided by the IHDS contractor.

For anthropometric comfort, the data recorded by the flight simulator monitor and the subjective questionnaires shall be reviewed for occurrences of IHDS removal during the flight

simulation, severe irritations, headaches or pressure points (hot spots). The frequency of helmet position adjustments shall also be reviewed.

3.1.4.1.6. Ballistic protection

3.1.4.1.6.1. Objective

To determine the maximum velocity at which a caliber .22 (type 2) fragment simulating projectile shall not completely penetrate or cause spalling, petaling, or cracking of the IHDS system or its protective visor.

3.1.4.1.6.2. Criteria

The IHDS system shall provide a minimum V_0 BL(P) ballistic protection of 170 meters per second (558 feet per second) when tested with a caliber .22 (type 2) fragment simulating projectile. There shall be no complete penetration, spalling, petaling, or cracking of the IHDS shell or protective visor when impacted with a caliber .22 (type 2) fragment simulating projectile at velocities up to 170 meters per second. At least 3 successful impacts shall be made at projectile velocities between 167 and 170 meter per second. At least 2 additional impacts shall be made at a projectile velocity between 170 and 172 meters per second. Any projectile impact at a velocity below 170 meters per second which either completely penetrates or causes spalling, petaling, or cracking of the IHDS system or visor shall result in failure of this requirement.

3.1.4.1.6.3. Apparatus

The fragment simulator shall be a caliber .22, type 2, in accordance with MIL-P-46593A, Projectile, calibers .22, .30, .50 and 20-mm fragment - simulating. A pneumatically charged accumulator, or equivalent, shall be used to propel the simulation fragment projectile to the required velocity. The projectile's velocity shall be measured with a high-velocity lumiline screens and an electronic counter type chronograph which measures to at least the nearest microsecond (10^{-6} second). The IHDS system shall be mounted onto a polystyrene headform covered with a sheet of aluminum foil, 0.05 millimeters thick. This foil shall act as a witness plate for penetration.

3.1.4.1.6.4. Procedure

The projectile impact test for the IHDS helmet shall be conducted in accordance with MIL-STD-662E, V50 ballistic test for armor, using a caliber .22 type 2 fragment simulating projectile. The projectile impact test for the visor(s) shall be conducted in accordance with MIL-V-43511C, Military specification: Visors, flyer's helmet, polycarbonate. The IHDS system or visor shall be mounted with the area to be impacted normal to the line of fire. Subsequent impacts shall be aimed at least 2 times the damage diameter away from a previous impact. Impacts shall be at least 2.5 cm from the edge of the IHDS shell or visor.

3.1.4.1.6.5. Analytical method

The witness plate shall be examined for penetration. A complete penetration is recorded when a hole is located in the witness plate. If no hole is evident, a partial penetration is recorded. The visor shall be examined for spalling, petaling, and cracking by holding it up to light to observe the damage.

3.1.4.1.7. Helmet-mounted display breakaway force

3.1.4.1.7.1. Objective

This test is required only if any IHDS components are designed to release from the IHDS when subjected to accelerations. The objective of this test is to evaluate the release characteristics of the breakaway components and to ensure that the components do not contact the headform during breakaway.

3.1.4.1.7.2. Criteria

3.1.4.1.7.2.1. Component breakaway

When subjected to an acceleration of 9 G or less in any vector within the limits described in Figure 36a-c, the designed breakaway components shall not separate from the IHDS. When subjected to an acceleration of 15 G or greater, in any vector within the limits described in Figures 36a-c, the breakaway components shall separate from the IHDS.

3.1.4.1.7.2.2. Facial contact

The breakaway components shall not contact the headform's forehead, eye socket, or facial regions at any acceleration level or vector during these tests.

3.1.4.1.7.3. Apparatus

A monorail drop tower shall be used to evaluate the breakaway characteristics of the applicable IHDS components. The headform shall be a 50 percentile male headform as described in USAARL Report No. 88-5, Anthropometry and mass distribution for human analogues, volume I: Military male aviators, or comparable. The headform shall have its forehead, eye socket, and facial regions covered with a thin layer (approximately 2 mm) of pliable clay for positive indication of contact with the breakaway components. The acceleration levels shall be controlled by varying the energy attenuator at the impact location.

3.1.4.1.7.4. Procedure

The IHDS system shall be fitted to the test headform in accordance with the fitting procedures provided by the IHDS contractor. Care shall be taken to ensure that the electro-optic lenses are properly aligned with the headform eye position. The headform and IHDS system shall be raised to a drop height of 0.5 meter and released in a guided free fall. The acceleration pulse shall be controlled by using various energy attenuating materials to stop the falling headform and IHDS assembly. The G levels shall be recorded with a tri-axial accelerometer and the resultant G level determined. The headform shall be positioned and oriented in accordance with Figure 36a-c. The resultant G levels, headform positions, and breakaway characteristics shall be recorded. Any contact to the headform's facial regions shall be documented and photographed.

3.1.4.1.7.5. Analytical method

The recorded G levels at which the breakaway components either remain attached or separate from the IHDS assembly shall be compared against the specified criteria.

3.1.4.2. Subsystem/component tests

The following tests are applicable to either the protective helmet or head tracking/aiming subsystems.

3.1.4.2.1. Protective helmet shell tear resistance

3.1.4.2.1.1. Objective

To measure the impact tear resistance of the helmet shell.

3.1.4.2.1.2. Criterion

The helmet shell shall not allow a tear length greater than 5.0 centimeters when struck by a five kilogram tear penetrator at an impact velocity of 5.4 to 5.6 meters per second.

3.1.4.2.1.3. Apparatus

A monorail drop tower shall be configured as shown in Figure 37. The tear penetrator is shown in Figure 38. The helmet shell shall have the inner components (i.e., earcups, energy absorbing liner, fitting liner, electro-optics, etc.) and any exterior components (i.e., visor, visor housing, etc.) removed to allow testing of the shell. The shell shall be rigidly supported around the penetration area to reduce shell flexure. The helmet shell support fixture is shown in Figure 39.

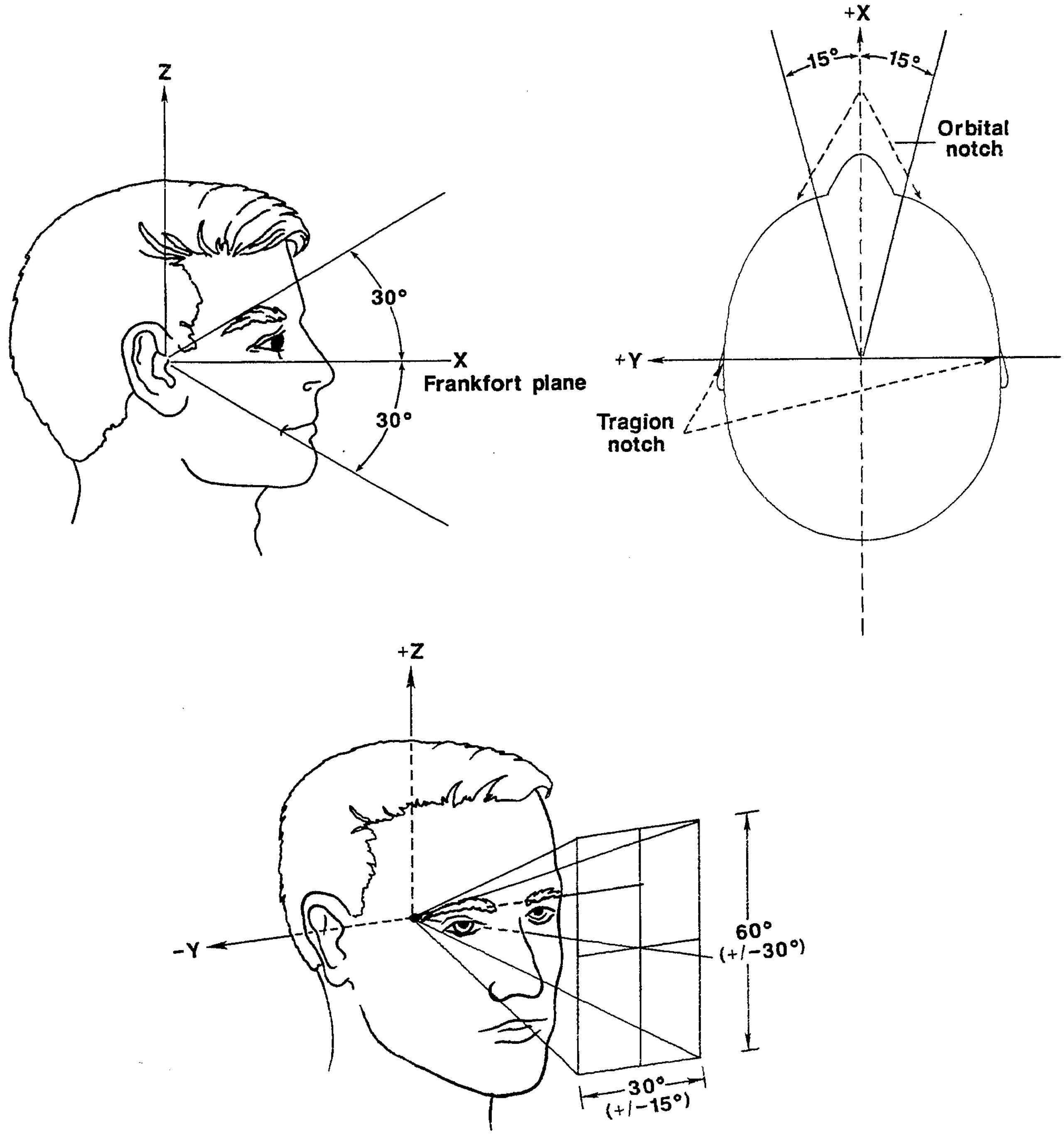


Figure 36. Vector limits for HMD breakaway force.

3.1.4.2.1.4. Procedure

The helmet shell shall be secured to the supporting fixture. The helmet shell shall be positioned such that the initial contact point creates a tangent line which is at a 45 degree angle relative to true vertical. The penetrator shall be raised to a height sufficient to create an impact velocity of 5.4 to 5.6 meters per second. The penetrator shall then be released in a guided free fall and allowed to strike the helmet shell. The tear length shall be measured along the outer shell surface and recorded.

3.1.4.2.1.5. Analytical method

A direct comparison shall be made of the measured tear length against the maximum allowed tear length.

3.1.4.2.2. Protective helmet chinstrap assembly integrity

3.1.4.2.2.1. Objective

To measure chinstrap system strength and elongation when quasi-statically loaded to 1956 Newtons (440 pounds) and to assess the helmet's tendency to resist rotation resulting from the chinstrap loads.

3.1.4.2.2.2. Criteria

The helmet and chinstrap system shall withstand a 1956 Newton quasi-static load for not less than 30 seconds and the total elongation not exceed 25 millimeters. The system shall also resist rotations when loaded.

3.1.4.2.2.3. Apparatus

A quasi-static test machine capable of applying and sustaining a load of 1956 Newtons shall be utilized in this evaluation. The IHDS shall be mounted onto a headform and the chinstrap is routed around a simulated chin. The load is applied through the simulated chin while the headform is held stationary. This test setup is shown in Figure 40.

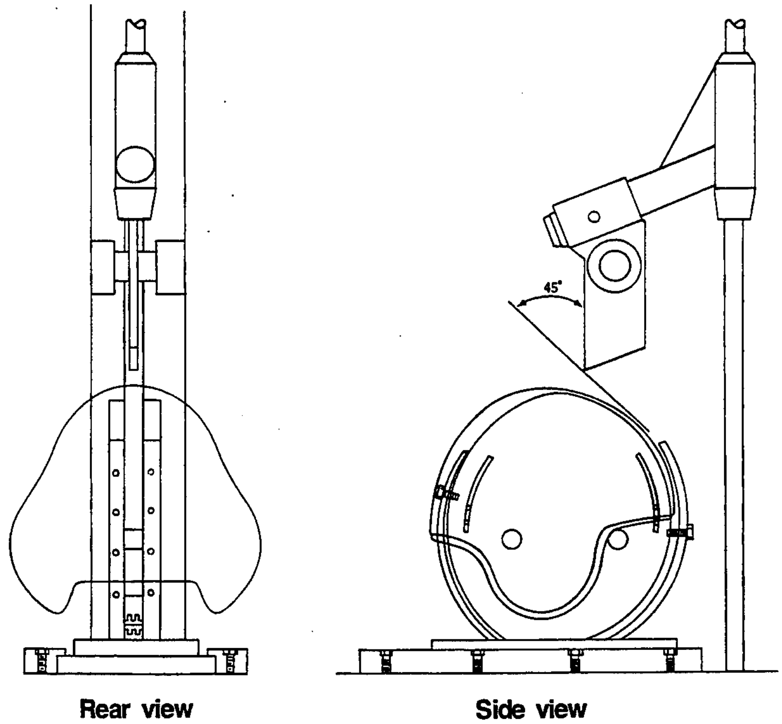


Figure 37. Drop tower setup for helmet tear test.

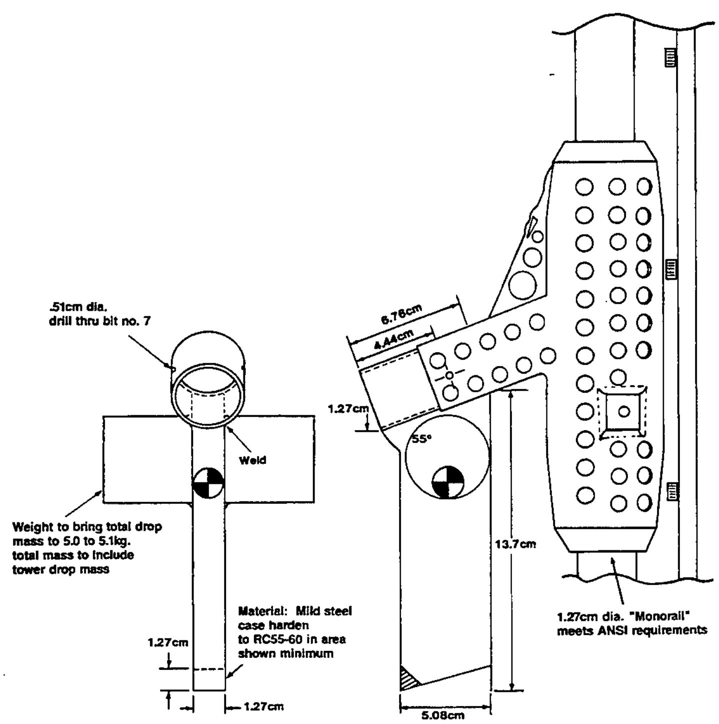


Figure 38. Tear penetrator.

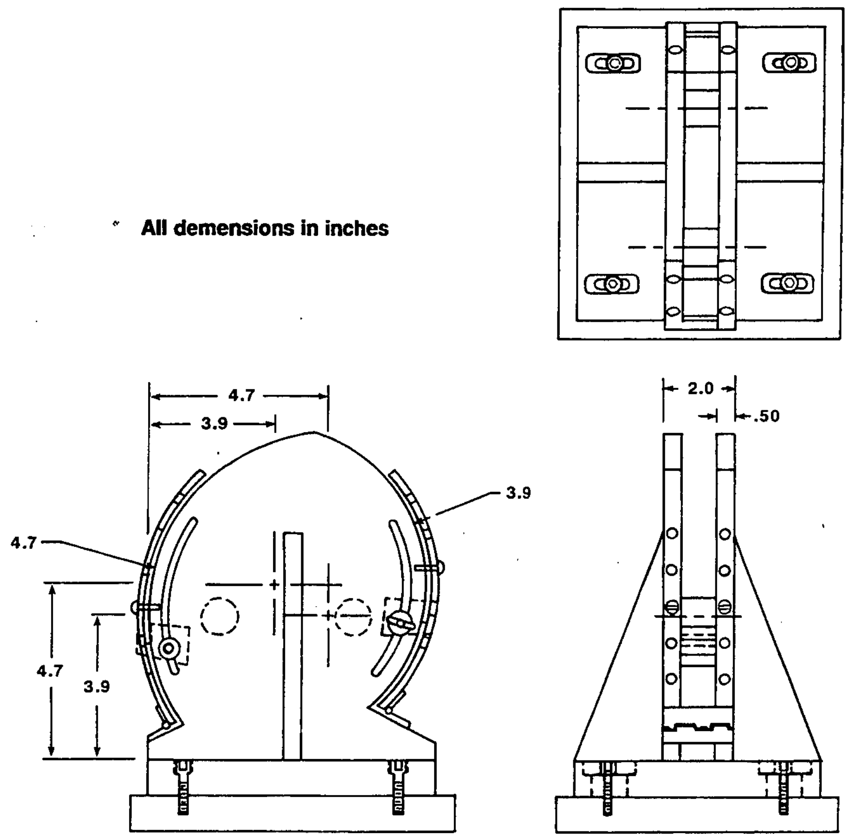


Figure 39. Helmet tear test support fixture.

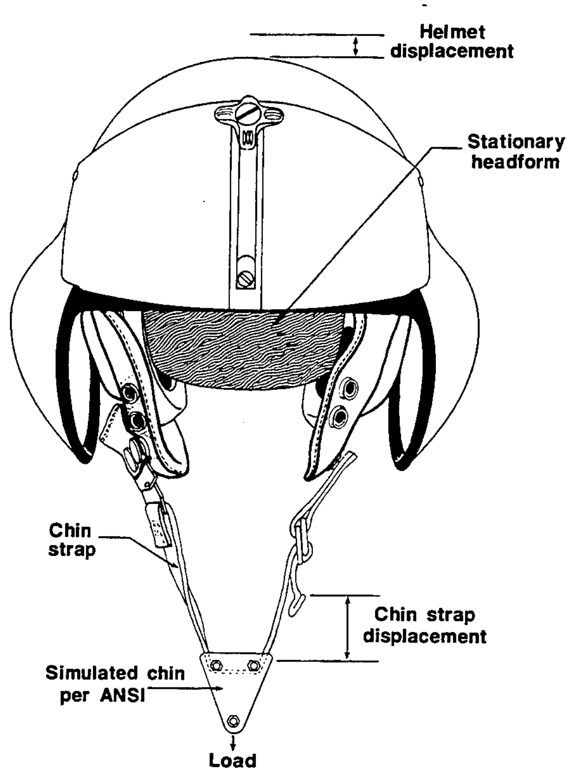


Figure 40. Test setup for chinstrap elongation.

3.1.4.2.2.4. Procedure

The IHDS is fitted to the test headform and the chinstrap is properly routed around the simulated chin. The chinstrap is then pre-loaded to 111 Newtons (25 pounds) and the helmet crown and simulated chin positions are recorded. The load is then increased to 1956 Newtons (440 pounds) and sustained at this level for 30 seconds. After sustaining the 1956 Newton load for 30 seconds, the new helmet crown and simulated chin positions are recorded and the load removed.

3.1.4.2.2.5. Analytical method

Total chinstrap elongation is determined by subtracting the helmet displacement from the simulated chin displacement. Total chinstrap elongation (C_T) is calculated by:

$$C_T = (C_f - C_i) - (H_f - H_i)$$

where

C_i = chin initial position
C_f = chin final position
H_i = helmet crown initial position
H_f = helmet crown final position

3.1.4.2.3. Head tracking/aiming system motion box size

Note: Testing of the following head tracking/aiming system parameters is highly dependent on the tracking technology and may require specialized test equipment available only from the system manufacturer. Some tests may not produce discrete parametric values and, instead, may have to be accepted on the basis of lack of unsatisfactory performance.

3.1.4.2.3.1. Objective

To determine the linear dimensions of the space volume within which the head tracking/aiming system can accurately maintain a valid line-of-sight.

3.1.4.2.3.2. Criteria

The head-tracking/aiming system shall allow the head to move freely within a motion box of TBD dimensions without system degradation. The head motion box for the AH-64 IHADSS is a minimum of 12 inches forward, 1.5 inches aft, ±5 inches laterally, and ±2.5 inches vertically from the design eye position.

3.1.4.2.3.3. Apparatus

The following components of the head-tracking/aiming system under test are required: helmet, sensors/sources (acoustical, magnetic, electro-optical, etc.), boresight unit, and associated

processing electronics. Testing is performed at a test station which consists of an appropriate holding fixture and interface test set. The holding fixture must be designed to position the helmet and sensor/source(s) at the nominal relative aircraft coordinates. This fixture also must allow for the mounting of the helmet for 3-axis translation of the helmet through ranges which exceed the motion box size criteria. The interface test set must be capable of obtaining and displaying the interface signals of the head position sensing electronics. The function of the interface test set is to display the head position output signal. (Note: This test requires specialized interfacing electronics which may only be available from the head-tracking/aiming system manufacturer.)

3.1.4.2.3.4. Procedure

The system under test is mounted in the test station and the helmet is placed in the holding fixture. The helmet is positioned along the boresight unit axis and this position (angle) is established with the test set. The helmet is then translated in increments through the individual ranges of motion for each axis. The head position output signal is recorded for each position. The positions (and related range) for which the output signal are invalid are recorded as the limits of the motion box. (Note: The procedure for this test may require modification to adapt to the specialized test station and interface electronics provided by the manufacturer.)

3.1.4.2.3.5. Analytical method

A 3-dimensional plot of the motion plot is created and compared to the test criteria.

3.1.4.2.4. Head tracking/aiming system update rate

3.1.4.2.4.1. Objective

To determine the rate at which the position of the helmet/head is sampled and used to provide drive inputs to the head-slaved sensor, usually expressed as a frequency (in hertz).

3.1.4.2.4.2. Criterion

The head-tracking/aiming system shall have an update rate of 60 Hz or greater.

3.1.4.2.4.3. Apparatus

A digital storage oscilloscope may be used to measure the timing signals needed to calculate update rate.

3.1.4.2.4.4. Procedure

In general, the update rate is determined using timing diagrams for the systems/subsystems involved in the determination of the line-of-sight angle(s) and the associated communication busses.

3.1.4.2.4.5. Analytical method

Calculated update rate is compared to test criterion.

3.1.4.2.5. Head tracking/aiming system jitter

3.1.4.2.5.1. Objective

To measure the variations in head position output data due to vibrations, voltage fluctuations, control system instability, and other causes.

3.1.4.2.5.2. Criterion

The overall jitter due to system noise, vibration effects, etc. shall be less than TBD.

3.1.4.2.5.3. Apparatus

The following components of the head-tracking/aiming system under test are required: helmet, sensors/sources (acoustical, magnetic, electro-optical, etc.), boresight unit, and associated processing electronics. Testing is performed at a test station which consists of an appropriate holding fixture and interface test set. The holding fixture must be designed to position the helmet and sensor/source(s) at the nominal relative aircraft coordinates. This fixture also must allow for the mounting of the helmet for 3-axis rotation of the helmet through ranges which encompass the motion box size. The interface test set must be capable of obtaining and displaying the interface signals of the head position sensing electronics. The function of the interface test set is to display the line-of-sight output signals. (Note: This test requires specialized interfacing electronics which may only be available from the head-tracking/aiming system manufacturer.)

3.1.4.2.5.4. Procedure

The interface test set is connected so as to monitor the line-of-sight outputs. The data scatter of the outputs is recorded for a number of selected static orientations of the helmet for a designated time period. The mean and standard deviation of the outputs for the selected helmet orientations are calculated.

3.1.4.2.5.5. Analytical method

Measured jitter is compared to test criterion.

3.1.4.2.6. Head tracking/aiming system pointing angle accuracy

3.1.4.2.6.1. Objective

To measure the error between the aviator's line-of-sight (when aligned with the sighting reticle) and the sensor's and/or weapon system's line-of-sight output.

3.1.4.2.6.2. Criterion

Pointing error shall be less than 0.1 degrees (1.7 milliradians) over the full head tracking/aiming system's angular range, as limited by the motion box.

3.1.4.2.6.3. Apparatus

A headform, a calibrated rotatable platform graduated to 0.1 degrees, a 36" x 36" target grid with lines separated by 0.1 degrees with the center marked, and a monitor with center clearly marked.

3.1.4.2.6.4. Procedure

The IHDS shall be properly fitted onto the headform with chin strap secured. This assembly shall then be positioned upon the calibrated rotatable platform with the center of rotation of the platform aligned with the center of rotation of the headform, and the zero degree mark of the platform aligned with the lateral intersection of the headform. The target grid shall be positioned perpendicular to the line-of-sight of the sensor and at a distance such that the separation of the grid lines subtends an angle of 0.1 degrees at the focal point of the sensor. The sensor shall be positioned laterally so that the image of the center mark of the target grid is coincident with the center mark of the monitor.

The IHDS/platform assembly shall be rotated to 5°, 15°, 45°, and 60° in the left and right directions. With each IHDS displacement, sensor output displacement shall be measured by noting the grid line which is aligned with the center mark of the monitor. Repeat for all displacements listed above.

An alternative procedure based on specialized manufacturer test sets may be used.

3.1.4.2.6.5. Analytical method

Head tracking/aiming system pointing accuracy is determined by comparing the angular displacement given by the sensor output to the actual IHDS/platform assembly displacement. Angular displacement given by the sensor output is calculated by multiplying 0.1 degrees by the number of grid lines displaced from center of the target. Any sensor angular displacement shall constitute a failure of the requirement for pointing error to be less than 0.1 degrees.

Measured error value is compared to test criterion.

3.1.4.2.7. Head tracking/aiming system pointing angle resolution

3.1.4.2.7.1. Objective

To determine the smallest increment in head position (or corresponding line-of-sight angle) which produces a difference in head tracking/aiming system output signal level.

3.1.4.2.7.2. Criterion

The head tracking/aiming system shall be capable of resolving changes in head position of 1.5 mm along all axes over the full motion box.

3.1.4.2.7.3. Apparatus

The following components of the head-tracking/aiming system under test are required: helmet, sensors/sources (acoustical, magnetic, electro-optical, etc.), boresight unit, and associated processing electronics. Testing is performed at a test station which consists of an appropriate holding fixture and interface test set. The holding fixture must be designed to position the helmet and sensor/source(s) at the nominal relative aircraft coordinates. This fixture also must allow for the mounting of the helmet for 3-axis translation (with 0.5 mm or better resolution) of the helmet through ranges defined by the motion box size. The interface test set must be capable of obtaining and displaying the interface signals of the head position sensing electronics. The function of the interface test set is to display the head position (line-of-sight angle) output signal. (Note: This test requires specialized interfacing electronics which may only be available from the head-tracking/aiming system manufacturer.)

3.1.4.2.7.4. Procedure

The system under test is mounted in the test station and the helmet is placed in the holding fixture. The helmet is positioned along the boresight unit axis and this position (angle) is established with the test set. From an arbitrary orientation (position) the helmet is translated along each axis in increments of 0.5 mm or less until the interfacing electronics providing readout of the output signals shows a digital increase. The head position output signal is recorded for each position. The total incremental change required to produce the output signal change along each axis is recorded. (Note: The procedure for this test may require modification to adapt to the specialized test station and interface electronics provided by the manufacturer.)

3.1.4.2.7.5. Analytical method

The measured minimum required increments are compared to the test criterion.

3.1.5. Acoustical

Acoustical testing is applicable to the IHDS as a total system and to the earphone/earcup subsystem. The acoustical system and subsystem/component test parameters are presented in Table 6.

Table 6.

Acoustical test parameters

Test	Section
System	
Real-ear attenuation	3.1.5.1.1.
Physical-ear attenuation	3.1.5.1.2.
Speech intelligibility	3.1.5.1.3.
Earphone/earcup	
Sensitivity	3.1.5.2.1.
Distortion	3.1.5.2.2.
Frequency response	3.1.5.2.3.

3.1.5.1. System tests

The following tests are applicable to the total system. A specific test may be performed for multiple system configurations.

The IHDS shall be subjected to a variety of evaluations to determine its acoustical characteristics and how well it meets the design criteria. The evaluations shall be conducted in the laboratory, using standardized methodology.

3.1.5.1.1. Real-ear attenuation

3.1.5.1.1.1. Objective

To determine the hearing protective characteristics of the IHDS. These data shall be used to develop Health Hazard Assessments (HHA) of the IHDS for use in the aviation environment.

3.1.5.1.1.2. Criteria

The real-ear attenuation of the helmet shall be no less than values shown in Table 7 for each of the indicated test frequencies.

Table 7.

Required real-ear attenuation in decibels (dB)

Frequency (Hertz)								
125	250	500	1000	2000	3150	4000	6300	8000
17	14	20	21	26	38	37	46	42

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.5.1.1.3. Apparatus

Testing shall be performed in an isolated sound room. The instrumentation will control a calibrated sound field to determine the hearing threshold of test subjects. A block diagram of the instrumentation used to perform the real-ear evaluation is shown in Figure 41.

3.1.5.1.1.4. Procedure

Real-ear attenuation of the hearing protection characteristics of the helmet shall be determined using the ANSI S12.6(1984) Method for the measurement of the real-ear attenuation of hearing protectors. A standard test consists of 10 normal hearing subjects (verified on a standard clinical audiometer according to ANSI S3.6-1969, Specification for audiometers) seated in a sound room with their heads placed at a fixed location. The helmet is fitted optimally for each test subject. The subject is instructed to adjust the stimulus level to his auditory threshold for each test frequency using a key pad to increase or decrease the level. This is performed for the two conditions of wearing (occluded) and not wearing (nonoccluded) the helmet. The test frequencies are defined as 1/3 octave bands of noise with center frequencies as given in Table 7. A minimum of four trials are conducted.

3.1.5.1.1.5. Analytical method

The mean of the four trials for each of the test frequencies is used as the threshold for the test conditions. The difference in threshold for the occluded and nonoccluded trials for each frequency defines the attenuation of the IHDS for that frequency. These mean values of measured real-ear attenuation are compared to minimum required values given in Table 7. Measured values shall be subjected to a student's t-test and shall not be less than values in the table using an alpha of 0.05.

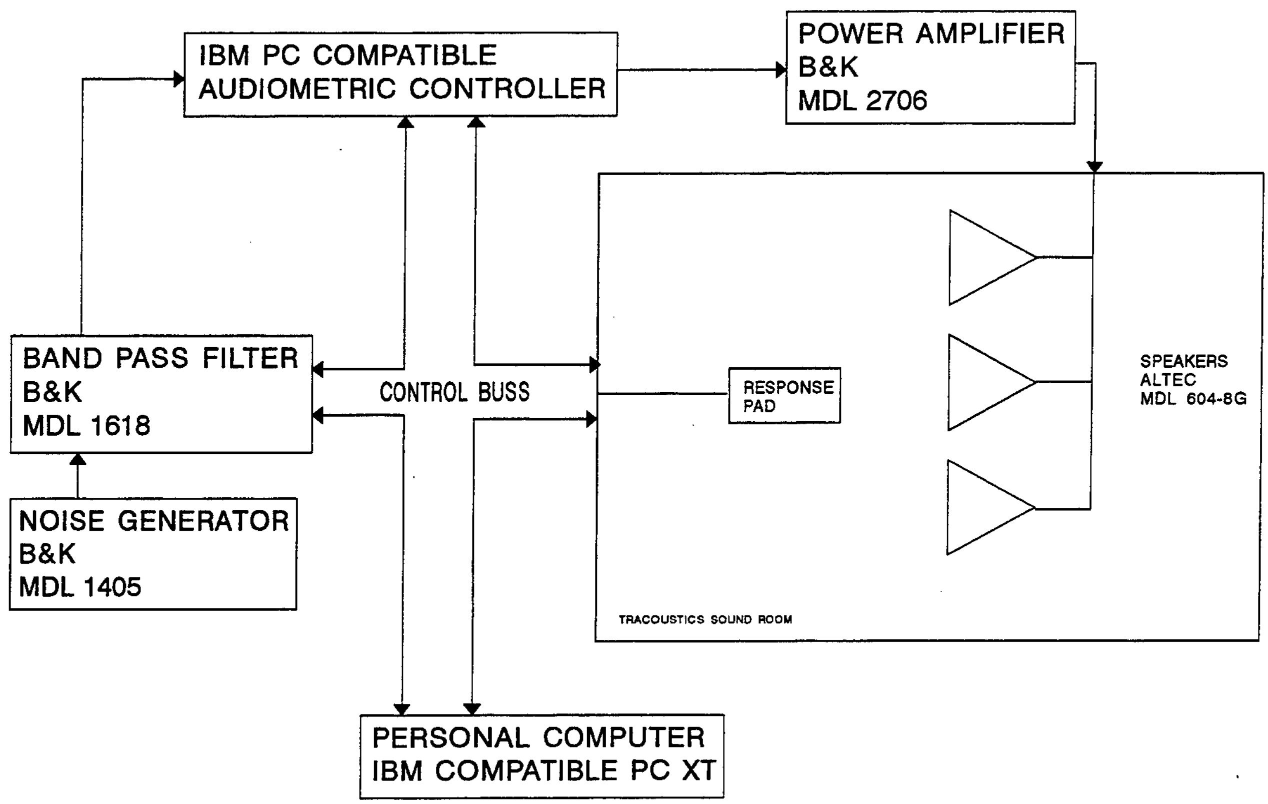


Figure 41. Block diagram for real-ear attenuation test system.

3.1.5.1.2. Physical-ear attenuation

3.1.5.1.2.1. Objective

The Physical-Ear Attenuation Test (PEAT) shall be performed for the purpose of establishing baseline sound attenuation data to be used for quality assurance of the IHDS during full production.

3.1.5.1.2.2. Criteria

Criteria will be developed using results from real-ear attenuation and PEAT measurements completed during the course of the helmet development.

3.1.5.1.2.3. Apparatus

Testing is performed in an acoustically treated sound room. The instrumentation for generating and measuring the required noise bands are depicted by the block diagram in Figure 42.

3.1.5.1.2.4. Procedure

Physical-ear attenuation of the hearing protective characteristics of the helmet is determined using procedure in MIL-STD-912 (Dec 1990), Physical ear noise attenuation testing. A standard test uses 10 college students with normal hearing. The subjects are required to sit in a hard walled sound room with a semi-diffuse sound field no greater than 105 adjusted decibels (dBA). Attenuation is defined as the difference in noise measured by the microphones located at the ear canal openings while wearing and not wearing the helmet.

3.1.5.1.2.5. Analytical method

The physical-ear attenuation of the left and right earcup shall be the difference in level, in decibels (dB), of the one-third octave test bands between the occluded and nonoccluded measurements for each earcup. Measured attenuation of the earcups shall be summarized and reported independently. The standard number of observations shall be 30 (10 subjects measured 3 times each). Results of PEAT shall be compared to the results of the S12.6 real-ear procedure (paragraph 3.1.5.1.1.) to establish PEAT attenuation requirements at each frequency described in paragraph 3.1.5.1.1.2.

3.1.5.1.3. Speech intelligibility

3.1.5.1.3.1. Objective

To determine the speech intelligibility characteristics of the IHDS in the specified helicopter noise environment.

3.1.5.1.3.2. Criteria

A score of 90 percent correct speech intelligibility using the Modified Rhyme Test (MRT) is required for the IHDS when evaluated in the target noise environment. For comparison purposes, the Central Institute of the Deaf Auditory Test W-22 Phonetically Balanced (PB) word list test (Newby, 1972) shall be performed and the score shall be compared to scores previously obtained with other helmets commonly used in Army aviation.

Where required, additional or alternate criteria from specification documents shall be used for this test.

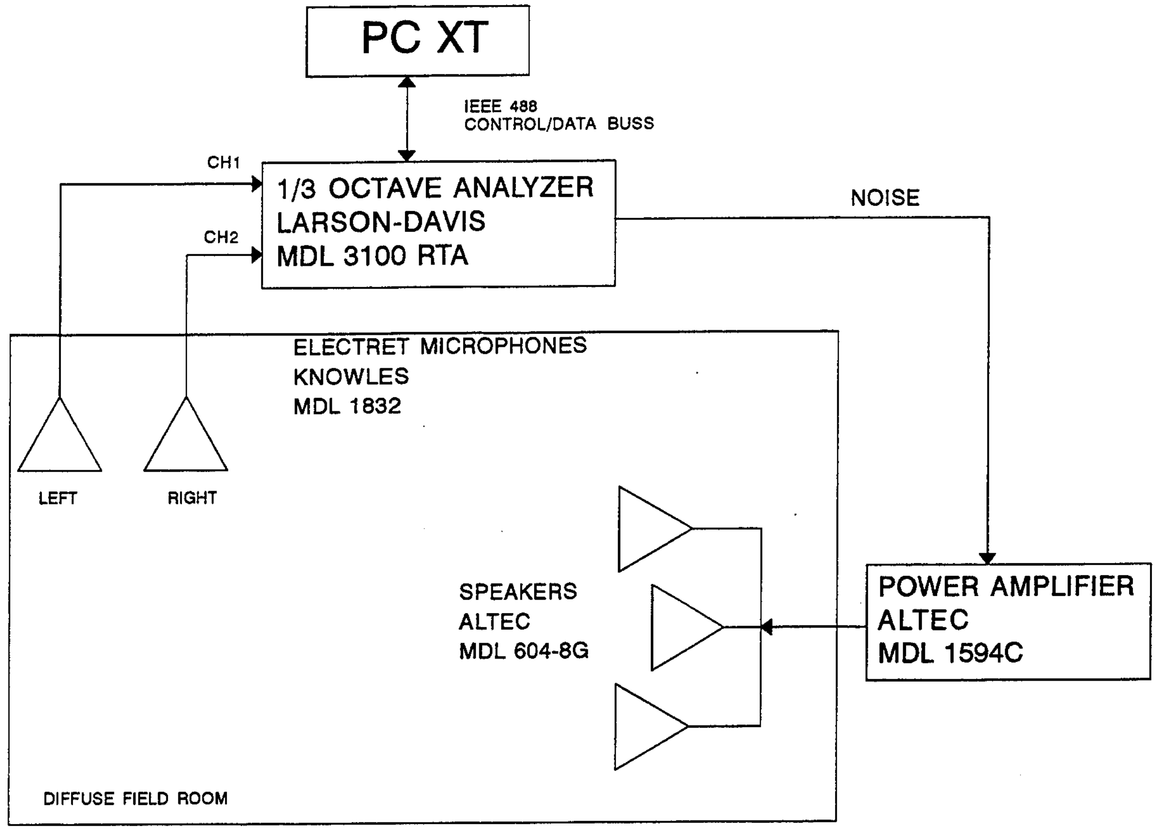


Figure 42. Block diagram for physical-ear attenuation test system.

3.1.5.1.3.3. Apparatus

Speech intelligibility shall be determined in an isolated sound room. The instrumentation will control a calibrated sound field, simulating a helicopter noise environment. Speech samples shall be presented to the subject through the IHDS using playback instrumentation which provides flat frequency responses from 100 to 10,000 hertz (Hz). The instrumentation shall be capable of accurate gain adjustment with a resolution of 1 dB over a range necessary to vary speech signals at the ear from 10 dB below speech reception threshold (SRT) to 30 dB above SRT for any subject used in the evaluation.

3.1.5.1.3.4. Procedure

Speech intelligibility shall be determined using a combination of the Modified Rhyme Test and the Phonetically Balanced word test. Testing is conducted using human subjects and performed in a sound field which simulates the target helicopter noise environment.

The MRT evaluation shall consist of words presented to the subject through the IHDS and responses will be made as to which of four possible similar sounding words is the presented word. The total list consist of fifty words.

The PB evaluation shall consist of fifty monosyllabic words presented to the subject through the IHDS at a level 10 dB and 15 dB above Speech Reception Threshold (SRT).

3.1.5.1.3.5. Analytical method

The speech intelligibility characteristics of the IHDS is determined by subjects' ability to understand speech samples of the MRT transmitted through the IHDS. This ability is directly related to the mean score (percent correct) for word samples presented to test subjects. The mean percent correct for ten subjects will be tested using a student's t-test and shall not be less than 90 percent correct using an Alpha of 0.05.

The PB word list score shall be compared scores of other helmets commonly used in Army aviation environments.

3.1.5.2. Subsystem/component tests

3.1.5.2.1. Earphone/earcup sensitivity

3.1.5.2.1.1. Objective

To measure the sensitivity of the earphone/earcup to determine compatibility of the IHDS with standard Army aviation communication equipment. Sound pressure levels which may exist in the earcup as a result of input from the communication systems shall be determined to provide input to the HHA.

3.1.5.2.1.2. Criteria

No criteria currently exist.

3.1.5.2.1.3. Apparatus

Sound Pressure Levels (SPL) shall be measured using a flat plate coupler. The earcup/earphone system will be driven by standard audio sound generating equipment.

3.1.5.2.1.4. Procedure

The earcup/earphone shall be placed on a calibrated flat plate coupler. The output of sound generating equipment will be used to drive the earphone/earcup at 1000 hertz (Hz) with a signal level of 500 millivolts root-mean-square (RMS). The resulting SPL shall be measured and used to compute the sensitivity, SPL/volt.

3.1.5.2.1.5. Analytical method

The measure of sensitivity shall be completed three times for each of the samples submitted for evaluation. Mean sensitivity and standard deviation shall be computed for the total sample.

3.1.5.2.2. Earphone/earcup distortion

3.1.5.2.2.1. Objective

To determine distortion characteristics of the earphone/earcup of the IHDS.

3.1.5.2.2.2. Criterion

Distortion is a component of speech communication signals which effects the resultant speech quality. Drive levels producing three percent distortion shall be within the intercommunication systems output characteristics. Distortion levels exceeding three percent are considered detrimental to speech intelligibility.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.5.2.2.3. Apparatus

Sound Pressure Levels (SPL) shall be measured using a flat plate coupler. The earcup/earphone system will be driven by standard audio sound generating equipment.

3.1.5.2.2.4. Procedure

The earcup/earphone shall be placed on a calibrated flat plate coupler. The output of sound generating equipment will be used to drive the earphone/earcup at 250, 500, 1000, 2000, and 4000 hertz. The driving level which produces three percent distortion shall be determined for each of the test frequencies. Measurements shall be completed three times for each of the samples submitted for evaluation.

3.1.5.2.2.5. Analytical method

Mean sensitivity and standard deviation for each frequency shall be computed for the total sample.

3.1.5.2.3. Earphone/earcup frequency response

3.1.5.2.3.1. Objective

To determine frequency response of the earphone/earcup system.

3.1.5.2.3.2. Criteria

Frequency response of the earcup/earphone shall not introduce unwanted or extreme variations in sensitivity across the speech spectrum. The frequency response measurement shall be used to provide insight into the speech intelligibility characteristics of the IHDS.

Where required, additional or alternate criteria from specification documents shall be used for this test.

3.1.5.2.3.3. Apparatus

Frequency response shall be measured, using an artificial ear with flat plate coupler. The earcup/earphone system will be driven by standard audio sound generating equipment.

3.1.5.2.3.4. Procedure

The earphone/earcup shall be placed and centered on the calibrated artificial ear. A wide band noise signal will be input into the earphone/earcup at a level of 85 dBA. The output shall be analyzed to determine the frequency response of the total earphone/earcup system.

3.1.5.2.3.5. Analytical method

The earphone/earcup frequency response shall be evaluated for difference in level relative to 1 kHz for one third octave center frequencies from 250 Hz to 4 kHz. Levels differences shall not exceed 10 dB.

3.2. Health hazard assessment (HHA)

The HHA identifies risks to the health and effectiveness of personnel who will test, use, and maintain the Integrated Helmet and Display System. It shall be conducted in general accordance with AR-40-10, Health hazard assessment program in support of the Army materiel acquisition decision process. A Health Hazard Assessment Report (HHAR) shall be prepared in the format prescribed and included in a combined test report. During the early phases of system development where insufficient data or hardware are available, an Initial Health Hazard Assessment Report (IHHAR) may be presented.

The primary process of the HHA is the analysis of the system under evaluation, including subsystems and components, for the purpose of identifying potential health hazards (Leibrecht, 1990). These hazards generally are classed into six major hazard categories: mechanical forces, chemical substances, biological substances, radiation, electricity, and environmental extremes.

Mechanical forces which can cause injury include acoustical energy (noise), vibration, shock, and trauma. Chemical hazards generally pertain to toxic materials and may exist in solid, liquid, or gaseous form. Biological hazards emanate largely from contamination by disease-causing microorganisms. Radiation concerns include nonionizing and ionizing types. Nonionizing radiation includes visible, infrared, and ultraviolet energy. Ionizing radiation includes x-rays. The major electrical hazard arises from the possibility of electrical shock. Ambient heat, ambient cold, and oxygen deficiency are the three major environmental extreme hazards.

The application of the identification process to Integrated Helmet and Display Systems requires the evaluation of the system and associated subsystems and components with respect to the hazard classes cited. Possible mechanical hazards include sharp edges or protrusions which may cause cuts or scrapes, insufficient head coverage to reduce crash impact trauma, excess head-supported weight resulting in increased crash forces, and optics which may impact the eyes during crash scenarios. Chemically active compounds such as paints, sealants, and adhesives are possible sources of chemical hazards. Fungi growth in helmet materials exposed to body secretions is a possible biological hazard. Since most IHDS designs use CRTs requiring high voltages, possible hazards of an electrical and radiation nature (e.g., x-rays) exist. The possibility of heat induced fatigue due to insufficient cooling mechanisms when wearing the helmet in a high ambient temperature environment is an example of an environmental extreme hazard.

Following identification of the potential hazards, an assessment of each hazard is performed. This assessment may involve testing of the hazard parameter and consequent data analysis to establish the level of hazard risk or it may involve the analysis of contractor provided data for the same purpose of establishing the risk level. In some cases, this assessment may be based on historical data acquired through an established history of the use of a specific device or material.

The estimation of the degree of risk associated with each hazard is accomplished by the assignment of a risk assessment code (RAC). The RAC is a combination of the severity of the possible consequence of the hazard and its probability of occurrence. Categories of severity as defined in AR 40-10 include: negligible (less than minor), marginal (minor), critical (severe), and catastrophic (death). Probability of occurrence is categorized as frequent, probable, occasional, remote, and improbable. Tables 8-10 show the assignment of risk assessment codes based on the severity and probability factors.

Based on the analysis of each hazard, a recommendation of actions to eliminate, reduce, or control the hazard shall be presented.

The final step of the HHA shall be the preparation of the HHAR (or IHHAR) which shall be included in the test and evaluation report.

Table 8.

Hazard probability of occurrence

Probability	Level	Definition
Frequent	A	Likely to occur frequently
Probable	B	Will occur several times in the life of the item
Occasional	C	Likely to occur sometime in the life of the item
Remote	D	Unlikely but possible to occur in the life of the item
Improbable	E	So unlikely, it can be assumed occurrence will not be experienced

Table 9.

Hazard severity

Severity	Level	Description
Negligible	IV	Less than minor
Marginal	III	Minor
Critical	II	Severe
Catastrophic	I	Death

Table 10.

Risk assessment codes

	Hazard probability				
Hazard severity	A	B	C	D	E
I1	1	1	1	2	3
II	1	1	2	2	4
III	2	3	3	4	5
IV	4	5	5	5	5

3.3. System safety assessment (SSA)

The SSA identifies system and personnel factors which may potentially result in injury or death to the operator under normal or nonroutine (e.g., alert, emergency, combat, etc.) operating conditions. It serves to establish safety requirements and training recommendations for operational and maintenance personnel. In addition, the SSA documents the occurrence, investigation, and proposed correction of mishaps or possible safety concerns associated with the system. The SSA is conducted using guidance provided in AR 385-16, System safety engineering and management and Military Standard 882B, System safety program requirements.

The contractor shall provide an IHDS data package to the test agency for the purpose of obtaining a safety of flight release prior to the first flight of each proposed helmet configuration. The data package is a summary of the safety related data collected by the contractor or materiel developer during the design and development of the system. In it, the contractor lists the extent of system specification compliance, potential hazards, and recommends procedures to minimize these hazards during testing and evaluation. Waivers granted on a specific configuration cannot be used for flight clearance on subsequent configurations.

3.3.1. Identification of safety issues

Prior to and during test and evaluation, each component, subsystem, and the system as a whole shall be evaluated for safety issues relating to the specific test parameter. Issues in these test areas that present or possibly present a safety risk shall be included in the system safety assessment. Military handbook, MIL-HDBK-759A, Human factors engineering design for Army materiel, provides basic principles about human behavior as related to safety which may serve to assist in tester in identification of possible safety issues.

3.3.2. Development of safety hazard log

During the operational assessment, all safety related incidents shall be documented using a form similar to that in Appendix 11, Safety Hazard Log Form. The forms includes a description of the incident, the hazard classification, and recommended action. Hazard classification shall be documented in accordance with the Hazard severity/risk assessment code matrix, MIL-STD-882B. All forms shall be compiled into the safety hazard tracking log which shall be maintained throughout all phases of development and testing for the specific system. Photo documentation shall be provided as required to clarify the scope of the hazard.

3.3.3. Safety training

Where provided by the contractor, the proposed training syllabus shall be validated for completeness in identifying safety issues, providing proper safety procedures, providing emergency procedures, and listing required safety equipment. Validation shall be accomplished by the appropriate Army responsible personnel, identified by military occupational specialty (MOS).

3.3.4. System safety assessment report (SSAR)

As required, the information obtained during the SSA may be reported in a System Safety Assessment Report (SSAR) or incorporated into an integrated test report.

3.4. Human factors engineering assessment (HFEA)

The human factors engineering assessment (HFEA) identifies issues which may impact the user's ability to perform the assigned mission while wearing the integrated helmet and display system (IHDS). These specific issues usually are identified during the technical program reviews and the system operational assessment. To assist in the evaluation of identified HFEA issues, these issues are designated as critical, major, or marginal.

An issue is characterized as critical if it may result in degraded performance likely to: (1) result in loss of life or serious injury, (2) cause extensive system damage, or (3) result in mission failure. A major issue is one which may: (1) degrade mission performance, (2) cause significant system damage, or (3) result in personal injury. An issue is marginal if it can not be classified as critical or major, but may over time or under stressful conditions result in mission degradation, system damage, or personal injury.

The reporting of HFEA issues shall include a description of the system/component problem area, its operational significance, and its issue classification (i.e., critical, major, or marginal). If within the expertise of the testing agency, a solution to the problem may be recommended.

The breadth of design possibilities in present and future helmet-mounted displays precludes a checklist approach to the characterization of human factors issues. However, military handbook, MIL-HDBK-759A, Human factors engineering design for Army materiel, provides detailed lists of generalized and specific parameters relating to controls, displays, connectors, cables, etc.

3.5. Manpower, personnel, and training assessment

The manpower, personnel, and training assessment evaluates the system with respect to its direct interface with the individual user. It addresses the issues of how many individuals are required for operation and support; the required education and skill levels of users and support personnel; and the amount, skill level, and adequacy of the training required and/or provided by the vendor.

Since the IHDS is a single user system, the major manpower concern is of support personnel requirements. The IHDS is assessed as to the number and skill requirements of identified support personnel with particular consideration for skills not currently supported by U.S. Army specialty skill identifiers (SSI). The technical levels required by support personnel to perform the required support are also assessed.

4. In-flight assessment

The purpose of the in-flight assessment is to evaluate the in-flight performance and the logistic supportability of proposed Integrated Helmet and Display Systems under actual flight conditions. In addition, evaluations of in-flight human factors and system safety issues are performed and documented.

4.1. Receipt inspection

4.1.1. Objective

To determine whether the test items, ancillary items, and system support package (SSP) are complete and ready for testing.

4.1.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.1.3. Procedure

Upon receipt, the test items, shipping containers, and SSP shall be examined for damage which may have occurred prior to or during shipment and for appropriate warning/caution labels. Photographs shall be taken for documentation, as required.

The equipment shall be unpacked, inventoried, and compared to the SSP components list and/or shipping documents for verification. Shortages shall be recorded and reported as appropriate.

Pretest services and/or operational checks shall be accomplished in accordance with instructions provided in the SSP. A Field Evaluation Initial Inspection Checklist (Appendix 12) shall be completed.

4.1.4. Analytical method

The test items shall be considered ready for test if there are no uncorrected discrepancies that preclude initiation of test. The SSP must be complete prior to starting the test.

4.2. Physical characteristics

4.2.1. Objective

To collect data for a reliability assessment of the test item.

4.2.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.2.3. Procedure

The integrated helmet and display system shall be properly fitted, adjusted, and worn by the test participants in accordance with instructions contained in the draft technical manuals (DTMs). The aviator test participants shall wear the system in conjunction with various combinations of chemical/biological (CB) and aviation life support equipment during day, night, and nap-of-the-earth (NOE) flights.

System operating time shall be recorded to the nearest tenth of an hour on an IHDS utilization log (Appendix 13). A detailed narrative description of all applicable reliability incidents and/or failures of the IHDS components shall be documented.

4.2.4. Analytical method

Reliability data shall be reviewed, and the results shall be compared to the criteria, if any, and presented in tabular and narrative form in the final report.

4.3. Reliability

4.3.1. Objective

To collect data for a reliability assessment of the test item.

4.3.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.3.3. Procedure

The IHDS shall be properly fitted, adjusted, and worn by the test participants in accordance with instructions contained in the draft technical manuals (DTMs). The aviator test participants shall wear the IHDS in conjunction with various combinations of chemical/biological and aviation life support equipment during day, night, and nap-of-the-earth flights.

The IHDS operating time shall be recorded to the nearest tenth of an hour on an IHDS utilization log (Appendix 13). A detailed narrative description of all applicable reliability incidents and/or failures of the IHDS components shall be documented.

4.3.4. Analytical method

Reliability data shall be reviewed, and the results shall be compared to the criteria, if any, and presented in tabular and narrative form in the final report.

4.4. Logistic supportability

4.4.1. Design for maintainability

4.4.1.1. Objective

To assess maintainability characteristics of the IHDS.

4.4.1.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.4.1.3. Procedure

a. The IHDS shall be maintained in accordance with the maintenance concept and instructions contained in the technical manuals. Soldier operator maintainer test and evaluation (SOMTE) personnel shall perform all aviation unit maintenance (AVUM) and aviation intermediate maintenance (AVIM) tasks. Comments by maintenance personnel concerning unusual, difficult, or excessive numbers of maintenance actions shall be recorded.

b. A descriptive narrative record of all scheduled and unscheduled maintenance actions required shall be compiled on a Supportability analysis chart (Appendix 14). This will include the following information:

(1) Total system time to date.

(2) Chargeability of each incident or malfunction relative to failure or nonfailure.

(3) Number of maintenance personnel required.

(4) Active maintenance time (clock minutes).

c. The project officer shall complete a Supportability design checklist (Appendix 15) based on inspection of the test items, observations of the maintenance actions, and a review of comments by maintenance personnel.

4.4.1.4. Analytical method

a. A point estimate of mean time to repair (MTTR) shall be calculated for each level of maintenance as follows:

$$MTTR = \frac{\text{Total unscheduled maintenance time (in minutes)}}{\text{Total number of maintenance actions}}$$

b. The completed Supportability design checklist and Supportability analysis chart shall be reviewed to identify characteristics of the test items or SSP which are prejudicial to ease-of-maintenance and/or do not adhere to sound maintenance practices. A narrative assessment shall be included in the final report.

4.4.2. Supply support

4.4.2.1. Objective

To assess adequacy of the repair/replacement parts provided in the SSP.

4.4.2.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.4.2.3. Procedure

a. The test items shall be maintained using repair/replacement parts contained in the SSP.

b. Parts consumption data shall be compiled by recording all parts required during the test on a Supply support chart (SSC) (Appendix 16) in accordance with Test operation procedure (TOP) 7-3-507.

c. Comments from user and/or maintenance personnel concerning interchangeability, standardization, ease of replacement, or inadequacies between the new and replaced parts shall be recorded.

4.4.2.4. Analytical method

The data recorded will be reviewed and an assessment made as to the adequacy of the parts. The assessment shall include information concerning impact on operation and maintenance of the test items and suggested corrective action if applicable.

4.4.3. Technical data equipment publications

4.4.3.1. Objective

To assess adequacy of the technical publications provided in the SSP.

4.4.3.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.4.3.3. Procedure

a. The test items shall be used in accordance with the instructions contained in the technical manuals provided in the SSP. All test participants shall have their IHDS fitted and adjusted as stated in the technical manual to assure that the fitting/adjustment instructions are adequately assessed.

b. The project officer shall review the technical manuals for completeness, clarity, and accuracy of content. Comments shall be obtained from user and maintenance personnel and recorded. Discrepancies and suggestions shall be submitted on Department of the Army (DA) Form 2028, Recommended changes to publications and blank forms (Appendix 17).

c. A Technical data/equipment publications chart (Appendix 18) shall be completed.

4.4.3.4. Analytical method

The data recorded during the test shall be reviewed and the results summarized in the final report.

4.4.4. Personnel and training

4.4.4.1. Objective

To assess adequacy of the military occupational specialty (MOS) and the training requirements required to support the test items under established maintenance concept.

4.4.4.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.4.4.3. Procedure

a. Test support participants shall maintain the test items in accordance with instructions provided in the SSP. The names, MOSs, and skill levels of these personnel shall be recorded.

b. An outline and/or narrative description of the training or additional training required shall be recorded.

c. Tasks that are difficult to perform shall be analyzed to determine if the training received caused the difficulty or if new skills are required.

4.4.4.4. Analytical method

The data shall be reviewed to determine whether training/training devices are required. A narrative discussion concerning the need for additional training, different skills, etc., shall be included in the final report.

4.4.5. Support and test equipment

4.4.5.1. Objective

To assess adequacy of the support and test equipment planned for use in maintaining the test items.

4.4.5.2. Criteria

Applicable criteria from specification documents shall be used for this test.

4.4.5.3. Procedure

a. The AVUM and AVIM tasks shall be performed using tools and test equipment specified in the SSP. A Support and test equipment (STE) chart (Appendix 19) shall be completed listing all tools, special tools, and test equipment required whether provided in the SSP or not.

b. Comments from maintenance personnel concerning adequacy and need of the tools and STE provided by the SSP shall be recorded.

4.4.5.4. Analytical method

Discrepancies identified with the tools or STE required to support the test items shall be assessed and discussed in the final report. Suggested changes, improvements, or deletions shall be included as appropriate.

4.5. In-flight human factors engineering assessment (HFEA)

4.5.1. Human factors engineering (HFE) design characteristics

4.5.1.1. Objective

To investigate HFE design characteristics associated with the IHDS.

4.5.1.2. Criteria

The IHDS shall comply with the requirements specified in Military standard (MIL-STD) 1472D. Applicable portions of MIL-STD-1472D include:

-Para 4.0 - General requirements
-Para 5.1 - Control/display integration
-Para 5.2 - Visual displays
-Para 5.11.3 - Optical instruments and related equipment

4.5.1.3. Procedure

a. The human factors engineer shall review demonstration devices, engineering drawings, and system operation manuals. Specific areas for review are:

(1) Helmet fit, comfort, range of adjustment, and fit retention for the anthropometric range of aviators (5th-95th percentile, required; 1st-99th percentile, desired).
(2) Donning and doffing procedures.
(3) Boresight requirements/retention.
(4) Sensor image quality.
(5) Symbology.
(6) Field-of-view (FOV).
(7) Sensor/pilot offset and sensor slew rate.
(8) Sensor image quality during day, night, and adverse weather operations.
(9) Integration with the target acquisition system.
(10) Integration with the aircraft navigation system.
(11) Integration with the aircraft survivability equipment.
(12) Compatibility with life support systems.
(13) Compatibility with nuclear, biological, and chemical equipment.
(14) Compatibility with AN/AVS-6 night vision goggles.
(15) Registration/magnification.

b. Anthropometric measurements specified in Appendix 20 shall be collected on all flight crew test participants using the anthropometry equipment in the HFE instrumentation kit. Results shall be recorded on the Flight crew anthropometric data sheet (Appendix 20).

c. Prior to flight testing, three test participants (approximately 5th, 50th, and 95th percentile aviator face length, face breadth, and interpupillary breadth) wearing the aircrew uniform integrated battlefield (AUIB), survival armor recovery vest insert packets (SARVIP), SARVIP body armor, M43 protective mask, and NBC protective gloves shall be observed performing simulated flight scenarios. The scope of this assessment shall be to investigate the compatibility characteristics between the IHDS, AIS protective equipment, and pilotage requirements. Results shall be recorded on the HFE observation data sheet (Appendix 21).

d. Prior to flight testing, three test participants (approximately 5th, 50th, and 95th percentile aviator face length, face breadth, and interpupillary breadth) wearing AN/AVS-6 NVGs shall be observed performing simulated flight scenarios. The scope of this assessment shall be to investigate the compatibility characteristics between the IHDS, AN/AVS-6 NVGs, and cockpit lighting system. Results shall be recorded on the HFE observation data sheet (Appendix 21).

e. Field-of-view measurements shall be collected from three test participants (approximately 5th, 50th and 95th percentile aviator face length, face breadth, and interpupillary breadth) wearing the IHDS using the Clement-Clark Aimark (or equivalent) projection perimeter. Measurements shall be recorded for three conditions: total IHDS visor FOV, total IHDS sensor image FOV, and total IHDS symbology set FOV. Meridional measurements shall be collected monocularly for each eye at 15-degree increments with the participant's line-of-sight fixated on the perimeter target.

f. Look-under FOV measurements shall be collected from three test participants (approximately 5th, 50th, and 95th percentile aviator face length, face breadth, and interpupillary breadth) wearing the IHDS with AN/AVS-6 NVGs using the Clement-Clark Aimark projection perimeter. Meridional measurements shall be collected monocularly for each eye at 15-degree increments with the participant's line-of-sight fixated on the perimeter's target.

g. Three test participants (approximately 5th, 50th, and 95th percentile aviator hand circumference, hand breadth, and hand thickness) wearing standard flight gloves, cold weather gloves, and NBC protective gloves will assess the operability of the IHDS. The operability assessment shall focus on operating closures, making adjustments, connecting cables, attaching auxiliary equipment, and operating the visor assembly. Results shall be recorded on the HFE Observation Data Sheet (Appendix 21).

h. Three test participants (approximately 5th, 50th, and 95th percentile aviator face length, face breadth, and interpupillary breadth) shall wear the IHDS for a continuous 4-hour period, which shall include at least 2 hours of flight operations. Upon completion of the 4-hour period, a human factors engineer shall conduct a structured interview with each participant. The interview shall focus on IHDS fit, comfort, adjustment capability, fit retention, speech intelligibility, noise attenuation, depth perception, visual distortion, and interference with viewing cockpit displays characteristics. Results shall be recorded on the HFE 4-hour wear assessment interview guide (Appendix 22).

I. A Modified rhyme test (MRT) shall be conducted in accordance with Appendix E-3 of TOP 1-2-610. A human factors engineer shall read an MRT word list over the radio to the test participant (wearing the IHDS) in the aircraft. Measurements shall be recorded for three test conditions: aircraft hovering, aircraft flying 40 knots, aircraft flying at an airspeed that produces the highest noise level in dBA as determined by a sound level meter. The MRT shall be conducted with a minimum of three participants for each test condition.

j. Three test participants (approximately 5th, 50th, and 95th percentile aviator height and weight) wearing standard flight suit, SARVIP, SARVIP body armor, and standard flight gloves shall be observed performing IHDS donning and boresighting procedures. Time required to perform donning and boresighting procedures, associated compatibility problems, and test participant comments shall be recorded on the HFE observation data sheet (Appendix 21).

k. IHDS controls, imagery, and symbology shall be assessed by a human factors engineer in conjunction with the pilot test participants. Conformance to the requirements specified in MIL-STD-1295 shall be determined through document review and flight crew interviews.

l. Flight performance assessment.

(1) A total of 10 test participants (representing approximately 5th, 50th, and 95th percentile aviator face length, face breadth, and interpupillary breadth) wearing AIS life support equipment configurations A and B (Table 11) shall assess the adequacy of the IHDS during day, night, and adverse weather flight operations. Each test participant shall perform the tasks specified in the IHDS Flight Performance Assessment Record (Appendix 23). Basic flight tasks (e.g., maintain heading, altitude, airspeed, turns to a heading, climb and descend to a target altitude, unusual attitude recovery, etc) shall be performed with reference only to HMD symbology (i.e., under the hood).

Table 11.

Aircrew Integration Systems (AIS) life support equipment configurations.

Item	A	B
Standard flight suit	x	
Standard flight gloves	x	
RSU-21/P survival vest	x	
IHDS	x	
AUIB		x
NBC gloves		x
SARVIP		x
SARVIP armor		x

(2) An instructor pilot (IP) shall serve as the pilot in command and as a safety pilot for each flight. The IP shall utilize the IHDS flight performance assessment record (Appendix 23) as a gradeslip during the flight. All tasks shall be performed in the same sequence and location during each test flight.

(3) The IP shall rate flying performance subjectively but shall not discuss the flight performance or grading of a particular task or maneuver with the participant during the flight. Task ratings shall be retained by the human factors engineer for data reduction and performance comparison purposes only.

(4) Three test participants (approximately 5th, 50th, and 95th percentile aviator face length, face breadth, and interpupillary breadth) shall assess the IHDS integration with the aircraft weapons system. Each participant shall perform the tasks required to operate the rocket, air-to-air Stinger (ATAS), missile, and gun systems. This assessment shall investigate image quality, registration, magnification, FOV, sensor slew rate, and sensor/pilot offset. Results shall be recorded on the IHDS/weapon system integration assessment record (Appendix 24).

(5) Each test participant shall complete the HFE questionnaire (Appendix 25) upon completion of IHDS flight testing. A human factors engineer shall review questionnaire responses with each test participant in order to clarify the IHDS human factors engineering design characteristics.

4.5.1.4. Analytical method

a. The results of the HFE questionnaires, IP assessments, and HFE interviews shall be compiled and presented in narrative form. HFE design discrepancies shall be analyzed with respect to the potential for human error and the associated impact on flight operations.

b. The anthropometric data shall be converted to percentile values and presented in tabular form.

c. Results from the AIS life support equipment compatibility assessment, AN/AVS-6 compatibility assessment, and IHDS operability assessment shall be presented in narrative form. HFE compatibility discrepancies shall be analyzed with respect to their functional impact on system performance.

d. FOV measurements shall be presented in graphical form. Obstructions to vision that pose problems during flight shall be discussed in narrative form.

e. Results from the MRTs shall be scored and reported as percent speech intelligibility in tabular form.

f. Results from the IHDS donning and boresight assessment shall be presented in narrative form as to their functional impact on system performance.

g. Results from the 4-hour wear assessment shall be presented in narrative form as to their functional impact on crew performance.

h. Criteria 4.5.1.2 shall be considered met if the IHDS is in compliance with applicable sections of MIL-STD-1472D and MIL-STD-1295.

4.5.2. Human factors engineering design for maintainability

4.5.2.1. Objective

To investigate the HFE design for maintainability characteristics associated with the IHDS.

4.5.2.2. Criteria

The IHDS shall comply with the requirements specified in MIL-STD-1472D, paragraph 5.9, Maintainability.

4.5.2.3. Procedure

a. Height, weight, functional arm reach, vertical arm reach, hand circumference, hand breadth, and hand thickness of all MOS-qualified ground support/maintenance personnel shall be measured using the anthropometry equipment in the HFE instrumentation kit. Results shall be recorded on the Support/maintenance personnel anthropometric data sheet (Appendix 26).

b. Three MOS-qualified test participants (approximately 5th, 50th, and 95th percentile soldier height and weight) shall assess the compatibility of AIS life support equipment with IHDS maintenance operations. A human factors engineer shall observe each test participant performing installation/ removal procedures for all IHDS line replaceable units (LRUs) while wearing a normal duty uniform, and NBC protective gloves, mask and overgarment. Time to perform maintenance procedures, associated ALSE compatibility problems, and test participant comments shall be recorded on the HFE observation data sheet (Appendix 21).

c. A human factors engineer shall observe standard preflight/postflight system inspections and unscheduled system maintenance. Structured interviews shall be conducted during the test with MOS-qualified support/maintenance personnel to obtain subjective comments regarding maintainability of the IHDS. The Design for Maintainability Checklist (Appendix 27) shall be used as a guide during the interview.

d. MOS-qualified support/maintenance personnel shall complete the HFE maintenance questionnaire (Appendix 28) upon completion of system testing. A human factors engineer shall review questionnaire responses with each test participant in order to clarify the IHDS design for maintainability characteristics.

4.5.2.4. Analytical method

a. The support/maintenance personnel anthropometric data shall be converted to percentile values and presented in tabular form.

b. Time required to perform LRU installation/removal procedures, associated ALSE compatibility problems, and test participant comments shall be presented in narrative form.

c. Results collected from observation of preflight, postflight, and unscheduled maintenance operations shall be presented in narrative form.

d. Results collected from the HFE maintenance questionnaire (Appendix 28) shall be presented in narrative form.

e. HFE design for maintainability discrepancies reported in paragraphs 4.5.2.3a-d shall be analyzed with respect to their functional impact on maintenance operations. Photographs shall be provided as required to clarify the scope of the discrepancy.

f. Criterion 4.5.2.2 shall be considered met if the IHDS is in compliance with applicable sections of MIL-STD-1472D, paragraph 5.9, titled "Maintainability."

4.6. In-flight system safety assessment (SSA)

4.6.1. Objective

To investigate the safety characteristics associated with the IHDS system.

4.6.2. Criteria

The IHDS shall comply with the requirements specified in MIL-STD-1472D, para 5.13, Hazards and Safety. The IHDS shall allow for safe emergency egress from the aircraft within the 30-second requirement specified in MIL-STD-1472D, para 5.14.4.1.2.

4.6.3. Procedure

The developer's safety assessment report (SAR), hazard analysis, and the airworthiness release (AWR) shall be reviewed prior to flight testing to ensure that all known hazards are controlled with appropriate safety precautions and procedures.

Prior to flight testing, three test participants (approximately 5th, 50th, and 95th percentile male aviator height and weight) shall be observed performing emergency egress procedures while wearing ALSE configurations A and B (Table 11). Emergency egress trials shall begin with the test participant seated in a static aircraft, properly fitted with the IHDS. The restraint harness shall be fastened, and the participant's hands shall be positioned on the flight controls. Each test participant shall be instructed to exit the aircraft as fast and safely as possible. The egress trial shall commence at the data collector's signal and cease when the test participant has departed the cockpit and moved 5 feet away from the aircraft. Emergency egress time shall be measured to the nearest 0.1 second utilizing a digital stopwatch. Each test participant shall perform a minimum of four timed egress trials per ALSE configuration. During each trial, the IHDS shall be connected and installed as it would be for flight. The purpose of this portion of the test is to determine if the IHDS shall impede emergency egress. Disconnecting the IHDS wiring, connectors, or other attachments prior to egress actions shall not be permitted. Emergency egress times, associated problems, and test participant comments shall be recorded on the Emergency Egress Data Sheet (Appendix 29).

Three MOS-qualified SOMTE personnel shall complete the Human Factors Maintenance Safety Checklist (Appendix 30) during initial inspection of the IHDS. The maintenance safety checklist shall address safety characteristics associated with AVUM procedures and equipment required to support IHDS maintainability operations.

Personnel and equipment hazards identified during the test shall be subjected to an operating and support hazard analysis. Data from this analysis shall be recorded the Operating and support hazard analysis worksheet (Appendix 31).

4.6.4. Analytical method

Personnel and equipment hazards identified during the test shall be classified in accordance with MIL-STD-882B. Photographs and video tapes shall be provided as required to clarify the scope of the hazard.

Emergency egress times shall be presented in tabular form. Emergency egress problems and test participant comments shall be presented in narrative form. Safety discrepancies shall be analyzed with respect to their functional impact on safe and reliable emergency egress operations. Criteria 4.6.2. shall be considered met if all emergency egress trials are conducted without problems in less than 30 seconds.

Personnel and equipment hazards identified by the MOS-qualified SOMTE personnel shall be presented in narrative form. System design discrepancies shall be analyzed with respect to their functional impact on safe and reliable AVUM operations. Criteria 4.6.2. shall be considered met if no uncontrolled hazards exist and if adequate safety precautions and procedures are provided to protect personnel during maintenance operations.

5. Summary

Evaluation of integrated helmet and display systems should address operational performance, health hazards, safety, and human factors. This evaluation should consist of laboratory and in-flight assessments. Five strategies are employed to perform a full evaluation. These strategies are: (1) a system operational assessment, (2) a Health Hazard Assessment (HHA), (3) a Human Factors Engineering Assessment (HFEA), (4) a Systems Safety Assessment (SSA), and (5) a manpower, personnel, and training assessment.

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7. Appendixes

7.1. Appendix 1.

Glossary

Alignment: The relative positioning of one image to another in biocular/binocular viewing, expressed in units of angular deviation.

Anthropometry: Description of the physical variation in humans by measurement.

Attenuation: The reduction of a physical quantity. As referenced herein, acoustical attenuation refers to the reduction in sound level at the ear due to the presence of a hearing protective device and is expressed in units of decibels. Impact attenuation refers to the reduction in mechanical force transmitted through the protective helmet. Optical attenuation refers to the reduction in light energy (visible and nonvisible) transmitted through an optical medium, e.g., visor.

Audiometer: An instrument for measuring hearing acuity.

Beamsplitter: A mirror that reflects a portion of a beam of light and transmits a portion.

Binocular: A term pertaining to optical devices which provide two visual inputs from two sensors which are slightly displaced in space.

Biocular: A term pertaining to optical devices which provide two visual inputs from a single sensor.

Breakaway: The physical separation of a subsystem or component from the major system. Some IHDS designs may employ helmet-mounted displays, eye protection devices, etc. which actively or passively separate from the IHDS under crash conditions.

Brightness: The intensity of visual sensation.

Center-of-mass (CM): That point of a body or system of bodies which moves as though the system's total mass was located at that point.

Chroma: The dimension of the Munsell system of color which corresponds most closely to saturation.

Chromatic aberration: The failure of an optical system to focus different wavelengths (colors) of light at the same point, resulting in color fringes within the image.

Chromaticity: A description of the color property of light based on hue and saturation.

Closed state optical density: The state of maximum attenuation of the thermal/flashblindness protective device following activation.

Appendix 1 . (Continued)

Color discrimination: The identification of hues.

Comparator: A device used to measure small distances.

Contrast ratio (CR): A mathematical expression for the luminance difference between two areas. Multiple definitions are in common use. As used herein, contrast ratio is defined as [(foreground + background)/background].

Corresponding points: Refers to pairs of points (one each for left and right optics) which are defined by the intersection of parallel lines of sight from the two eyes with the optics.

Decibel (dB): Ten times the base 10 logarithm of the ratio of two power quantities.

Diopter: A unit expressing the refractive power of an optical system/component as the reciprocal of the focal length in meters.

Diplopia: The condition where a single object is perceived as two; double vision.

Design eye position: The midpoint of the line segment of the over the nose vision line connecting two points which represents the predicted eye positions of the extremes of the aircrew population.

Distortion: An unwanted variation in magnification with angular distance from the center of an optical component or system; any undesired change in the frequency or amplitude of an acoustical signal.

Dynamic retention: Pertains to preventing the loss of the helmet during a crash sequence.

Electro-optical display: A display in which information contained in an electronic signal is converted into a visible image.

Equivalent background input (EBI): A measure of the output luminance of an image intensifier with no input.

Exit pupil: The region where the observer's eye must be located in order to view the total field-of-view. In optics, it is the image of the aperture stop as formed from the image side of the optics.

Eye clearance distance: The minimum clearance from the closest display system component to the cornea of the eye. This parameter is important in determining system compatibility with devices, e.g., corrective lenses, protective masks, etc. (Also referred to as physical eye relief.)

Field-of-view (FOV): The maximum image angle of view that can be seen through an optical device.

Flat field: A display in which all picture elements are driven to equal levels, resulting in uniform luminance across the display.

Flat plate coupler: An artificial ear designed to make electro-acoustic measurements of earphone/earcup headphone systems.

Footcandle (fc): A unit of illumination equal to uniformly distributed flux of 1 lumen per square foot; 1 lux = 0.0929 fc.

Footlambert (fL): A unit of luminance equal to the average luminance of a surface emitting light at the rate of 1 lumen per square foot; 1 nit = 0.2919 fL.

Grey shades: Progressive steps in luminance where each step differs from contiguous steps by a prescribed ratio. Herein, steps of the square-root-of-two are used.

Hazard: An existing or likely condition that can cause injury, death, or reduction in health status.

Haze: Cloudiness in an optical material caused by the forward scattering of light.

Head-supported weight: The effective weight of a head borne system, as perceived by wearer. Practical measurements may exclude weight of cables 1 foot beyond helmet exit points.

Health hazard: A risk to the health and effectiveness of personnel who test, use, and maintain the system. Hazards can arise from characteristics of the system itself or from the environment in which it operates. These hazards generally are classed into five major hazard categories: mechanical forces, chemical substances, biological substances, radiation, and environmental extremes.

Helmet-mounted display (HMD): An optical/electro-optical device which, using the helmet as a mounting platform, presents information to the eye(s).
Human factors: Acceptable human engineering design criteria, principles, and practices.

Illuminant C: An incandescent tungsten lamp producing a relative spectral energy distribution approximating overcast skylight and having a correlated color temperature of approximately 6740 degrees Kelvin (K).

Image intensification (I^2): Sensor technology based on amplification of ambient light. Photons are imaged onto a photocathode which converts them into electrons. The number of electrons is multiplied and channeled onto a phosphor screen.

Image overlap: The portion of the total field-of-view of a biocular/binocular system that can be viewed simultaneously by both eyes.

Imagery: Reproduction of external scenes presented typically as an electronic picture on an optical/electro-optical display.

Interpupillary distance (IPD): The distance between the centers of the pupils of the two eyes.

Jitter: Small, rapid variations due to vibrations, voltage fluctuations, control system instability, and other causes.

Luminance: Luminous flux per unit of projected area per unit solid angle leaving a surface at a given point and in a given direction; measured in footlamberts (fL).

Luminous transmittance: The decrease in luminance of the outside world as seen through an optical component or system; usually expressed as a percentage.

Magnification: The ratio of image to object size.

Milliradian (mr): A unit of measurement of angle equal to 0.057 degrees or 3.43 arcminutes.

Modulation transfer function (MTF): The sine-wave spatial-frequency amplitude response used as a measure of the resolution of an imaging system.

Monocular: Referring to viewing by a single eye.

Motion box: The volume space in the cockpit within which the head-tracking sensors accurately can determine head position.

Nanometer (nm): One billionth (10^{-9}) of a meter.

Nanosecond (ns): One billionth (10^{-9}) of a second.

Neutrality: The characteristic of an optical medium which denotes reasonably flat transmittance over the visible spectrum.

Nuclear flashblindness protective device (NFPD): Any piece of equipment designed for the purpose of protecting the human eye against nuclear flashblindness effects.

Octave band: A band of frequencies whose highest frequency is twice its lowest frequency.

Appendix 1. (Continued)

Ocular: An eyepiece.

Open state luminous transmittance: The luminous transmittance of a thermal/flashblindness device while in its "OPEN" (transmitting) state.

Optical density (OD): The degree of attenuation of a transmitting medium expressed by the base 10 logarithm of (1/T), where T is the transmittance of the medium.

Optical eye relief: The distance along the optical axis from the last optical element to the pupil of the eye. This is often greater than the eye clearance distance.

Petaling: Condition of a surface where the material about a point of penetration is forced into a leaflike or petal form.

Photopic: Referring to the spectral sensitivity of the human eye due to the activity of the cones of the retina; exhibited under high light levels of illumination.

Phosphor: A luminescent material that converts part of its absorbed energy into emitted luminescent radiation. Phosphors are used in cathode ray tubes to convert energy from an incident beam of electrons into visible light.

Pointing accuracy: A measure of the error between pilot's line-of-sight (when aligned with the sighting reticle) and the sensor's and/or weapon system's line-of-sight.

Prismatic deviation: A measure of the angular deviation in a light ray that occurs when the ray passes through an optical medium whose boundaries are nonparallel.

Prism diopter: A unit representing the strength of a prism. It is numerically equal to 100 times the tangent of the angle through which the light rays are bent. One prism diopter equals 10 milliradians.

Raster: A predetermined pattern of scanning lines that provides uniform coverage of a scene; type of imagery in a cathode ray tube display.

Refractive power: The focusing effect of an optical component or system.

Reticle: A fine line pattern which is located at the focus of the objective of an optical device.

Safety: Accident free conditions.

Scotopic: Referring to the spectral sensitivity of the human eye due to the activity of the rods of the retina only.

See-through luminous transmittance: The decrease in luminance of an internal image source as it passes through the full optical system.

Slew rate: The rate of movement in a horizontal or vertical direction, or both.

Sound room: An acoustically damped room used for acoustic evaluation.

Spalling: The production of fragments from the surface of a material.

Spatial frequency: A measure of the number of cycles (light and dark regions) displayed across a display (or other defined distance).

Spectral transmittance: The amount of radiant energy passing through an optical component or system as a function of wavelength.

Spherical aberration: The failure of an optical component or system to focus all monochromatic paraxial and peripheral light rays at a single point.

Stereopsis: Binocular three-dimensional perception (depth) based on retinal lateral disparity.

Straie: Fine, hair-like lines visible due to abrupt variations in the index of refraction.

Symbology: Diagrammatic figures used to represent or identify specific characteristics, quantities, or objects.

Update rate: The rate at which the position of the helmet/head is sampled and used to provide drive inputs to the head-slaved sensor, usually expressed as a frequency (in hertz).

Vignetting: A graduated reduction in illumination at the edges of an image.

Visual acuity: A measure of the ability of the eye to resolve spatial detail. Snellen visual acuity commonly is used and is expressed as a comparison of the distance at which a given set of letters are read correctly to the distance at which the letters would be read by someone with clinically normal vision. Normal visual acuity is 20/20, which is equivalent to 0.29 milliradians (approximately 1 arcminute) of resolution.

Visual field: A plot of the available field of vision available when wearing a helmet, helmet-mounted display, etc.

7.2. Appendix 2.

Abbreviations

AIHS	Aircrew Integrated Helmet System
AIS	Aircrew Integrated Systems
ANVIS	Aviator's Night Vision Imaging System
AR	Army Regulation
ASBO	as seen by the observer
ATAS	air-to-air Stinger
ATHS	Automatic Targeting Handoff System
AUIB	aircrew uniform integrated battle
AVIM	aviation intermediate maintenance
AVUM	aviation unit maintenance
AWR	airworthiness release
CB	chemical/biological
CCD	charge-coupled device
CM	center-of-mass
CIE	Commission Internationale de l'Eclairage
CR	contrast ratio
CRT	cathode-ray-tube
DA	Department of the Army
dB	decibel
dBA	adjusted decibel
DMTF	dynamic modulation transfer function
DTM	draft technical manual
fc	footcandle
fL	footlambert
FLIR	forward-looking infrared
FOV	field-of-view
G	acceleration due to gravity
HDU	helmet display unit
HFE	human factors engineering
HFEA	human factors engineering assessment
HHA	health hazard assessment
HHAR	health hazard assessment report
HIDSS	Helmet Integrated Display Sighting System
HMD	helmet-mounted display

Hz	Hertz
IHADSS	Integrated Helmet and Display Sighting System
IHDS	Integrated helmet and display system
IHHAR	initial health hazard assessment report
I^2	image intensifier (intensification)
IMC	instrument meteorological conditions
IP	instructor pilot
IPD	interpupillary distance
K	Kelvin (temperature scale)
kHz	kilohertz (10^3 Hertz)
LHX	light helicopter experimental
LOS	line-of-sight
LR	letter report
LRU	line replaceable unit
MAC	maintenance allocation chart
MANPRINT	manpower and personnel integration
MHZ	megahertz (10^6 Hertz)
MIL-STD	military standard
MIPR	military interdepartmental purchase request
mm	millimeter
MOS	military occupational specialty
mr	milliradian
MRT	modified rhyme test
m/s	meters per second
MTF	modulation transfer function
MTTR	mean time to repair
NBC	nuclear, biological, and chemical
NFPD	nuclear flashblindness protective device
nm	nanometer
NOE	nap-of-the-earth
NVG	night vision goggle
OD	optical density

PB	phonetically balanced
PEAT	physical-ear attenuation test
PMO	program manager office
PMT	photomultiplier tube
PNVS	Pilot's Night Vision System
RAC	risk assessment code
RMS	root-mean-square
SAR	safety assessment report
SARVIP	survival armor recovery vest, insert, and packets
SOMTE	soldier operator/maintainer test and evaluation
SPL	sound pressure level
SRT	speech reception threshold
SSA	system safety assessment
SSAR	system safety assessment report
SSC	supply support chart
SSI	specialty skill identifier
SSP	system support package
STE	support and test equipment
TBD	to be determined
TECOM	U.S. Army Test and Evaluation Command
TOP	test operation procedure
USAARL	United States Army Aeromedical Research Laboratory

7.3. Appendix 3.

Laboratory evaluation initial inspection checklist

Date ____________ Inspection preformed by________________

Item identification ____

____

Received From ____

NOTE: Photographic documentation required for damages noted upon this initial inspection.

	Yes	No	N/A
1. Condition of shipping container:			
A. Any visible damage	___	___	___
B. Appropriate warning/caution labels	___	___	___
2. Is there visible damage to test item(s) at time of container opening?	___	___	___
3. Do shipping documents agree with contents? (Attach copy of shipping document to this form for records)			
A. Number and type of items	___	___	___
B. Serial number(s)	___	___	___

4. Visual inspection of item(s) for damage and/or defects:

A. Visors:
Broken, cracked, chipped, sharp edges, warped, coating, etc. ____________________

B. Helmet: Cracks, holes, scratches, etc. ____________________

C. Communication assembly:
Missing components, broken wiring, damaged components, etc. ____________________

D. Nuclear flashblindness protective device:
Missing or broken components, etc. ____________________

E. Helmet-mounted display: Missing or broken components, etc. ____________________

F. Display electronics: Missing or broken wires, cables, etc. ____________________

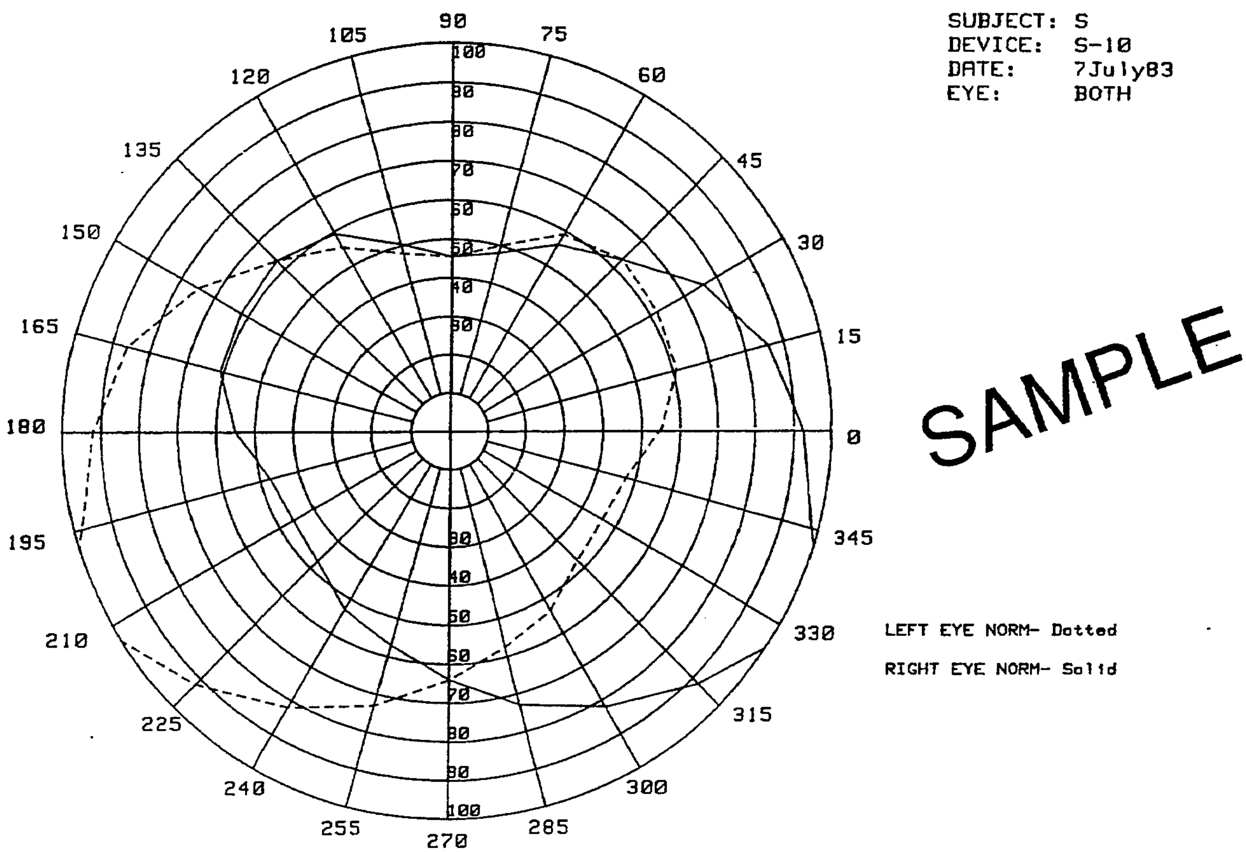
INCLUDE ANY ADDITIONAL REMARKS ON REVERSE SIDE OF THIS FORM

7.4. Appendix 4.

Visual field/field-of-view chart

VISUAL FIELD RECORD

SUBJECT: S
DEVICE: S-10
DATE: 7July83
EYE: BOTH



LEFT EYE NORM- Dotted

RIGHT EYE NORM- Solid

7.5. Appendix 5.

Relative spectral luminous efficiency values

Wavelength (nm)	Photopic	Scotopic
380	0.00004	0.00059
390	0.00012	0.00221
400	0.00040	0.00929
410	0.00120	0.03484
420	0.00400	0.09660
430	0.01160	0.19980
440	0.02300	0.32810
450	0.03800	0.45500
460	0.06000	0.56720
470	0.09100	0.67560
480	0.13900	0.79300
490	0.20800	0.90430
500	0.32300	0.98170
510	0.50300	0.99660
520	0.71000	0.93520
530	0.86200	0.81100
540	0.95400	0.64970
550	0.99500	0.48080
560	0.99500	0.32880
570	0.95200	0.20760
580	0.87000	0.12120
590	0.75700	0.06550
600	0.63100	0.03325
610	0.50300	0.01593
620	0.38100	0.00737
630	0.26500	0.00334
640	0.17500	0.00150
650	0.10700	0.00068
660	0.06100	0.00031
670	0.03200	0.00015
680	0.01700	0.00007
690	0.00820	0.00004
700	0.00410	0.00002
710	0.00210	0.00001
720	0.00105	0.00000
730	0.00052	0.00000

7.5. Appendix 5. (Continued)

Relative spectral luminous efficiency values

Wavelength (nm)	Photopic	Scotopic
740	0.00025	0.00000
750	0.00012	0.00000
760	0.00006	0.00000
770	0.00000	0.00000
780	0.00000	0.00000

7.6. Appendix 6.

Relative spectral distribution of CIE Source C

Wavelength (nm)	Relative Value	Wavelength (nm)	Relative Value	Wavelength (nm)	Relative Value
380	33.00	515	98.91	650	88.20
385	39.92	520	96.90	655	88.20
390	47.40	525	96.78	660	87.90
395	55.17	530	98.00	665	87.22
400	63.30	535	99.94	670	86.30
405	71.81	540	102.10	675	85.30
410	80.60	545	103.95	680	84.00
415	89.63	550	105.20	685	82.21
420	98.10	555	105.67	690	88.20
425	105.80	560	105.30	695	78.24
430	112.40	565	104.11	700	76.30
435	117.75	570	102.30	705	74.36
440	121.50	575	100.15	710	72.40
445	123.45	580	97.80	715	70.40
450	124.00	585	95.43	720	68.30
455	123.60	590	93.20	725	66.30
460	123.10	595	91.22	730	64.40
465	123.30	600	89.70	735	62.80
470	123.80	605	88.83	740	61.50
475	124.00	610	88.40	745	60.20
480	123.90	615	88.19	750	59.20
485	122.92	620	88.10	755	58.50
490	120.70	625	88.06	760	58.10
495	116.90	630	88.00	765	58.00
500	112.10	635	87.86	770	58.20
505	106.98	640	87.80	775	58.50
510	102.30	645	87.99	780	59.10

7.7. Appendix 7.

1931 CIE Tristimulus functions
(MIL-V-43511C)

Wavelength nm	$\bar{x}$	$\bar{y}$	$\bar{z}$
380	4		20
390	19		89
400	85	2	404
410	329	9	1570
420	1238	37	5949
430	2997	122	4628
440	3975	262	19938
450	3915	443	20638
460	3962	694	19299
470	2272	1058	14972
480	1112	1618	9461
490	363	2358	5274
500	52	3401	2864
510	89	4833	1520
520	576	6462	712
530	1523	7934	388
540	2785	9149	195
550	4282	9832	86
560	5880	9841	39
570	7322	9147	20
580	8417	7992	16
590	8984	6627	10
600	8949	5316	7
610	8325	4176	2
620	7070	3153	2
630	5309	2190	
640	3693	1443	
650	2349	886	
660	1361	504	
670	708	259	
680	369	134	
690	171	62	
700	82	29	
710	39	14	
720	19	6	
730	8	3	
740	4	2	
750	2	1	
760	1	1	
770	1		

7.8. Appendix 8.

Color discrimination test score sheet

FARNSWORTH DICHOTOMOUS TEST for Color Blindness—Panel D-15

Name..Age.............Date..............................File No......................

Department...Tester..

DICHOTOMOUS ANALYSIS

Type	Axis of Confusion			
PROTAN	(RED-bluegreen)	☐	PASS	☐
DEUTAN	(GREEN-redpurple)	☐		
TRITAN	(VIOLET-greenishyellow)	☐	FAIL	☐

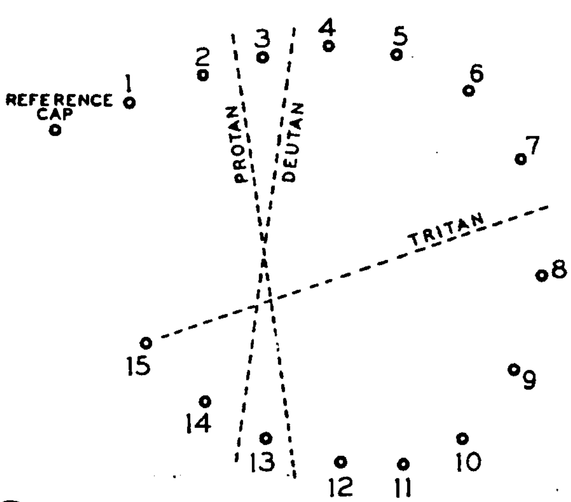
Test

Subject's Order __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

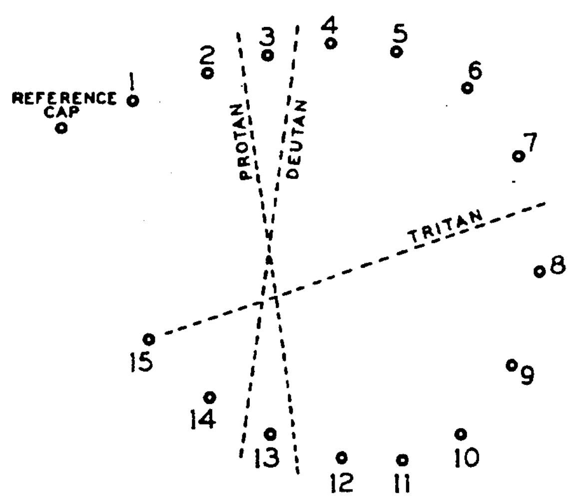
Retest 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15

Subject's Order __ __ __ __ __ __ __ __ __ __ __ __ __ __ __

TEST



RETEST



7.9. Appendix 9.

Natick Research, Development, and Engineering Center
guidance on laser (directed energy) protective visors
for the SPH-4B aviator's helmet

2 4 OCT 1990

STRNC-EP

MEMORANDUM FOR Commander, U.S. Army Support Activity
ATTN: STRAP-LM
2800 South 20th Street
Philadelphia, PA 19101

SUBJECT: Laser Protective Visors for the SPH-4B Aviator's Helmet

1. References:

a. Memorandum, Natick RD&E Center, STRNC-ICAA, 30 July 1990, subject as above.

b. Memorandum, Natick RD&E Center, STRNC-EP, 18 September 1990, subject: Laser Protective Visors for the SPH-4 Flyer's Helmet.

c. Telephone conversation between Natick (Mr. Moody) and Program Manager-Clothing and Individual Equipment (PM-CIE) (Ms. Webb), 1 October 1990, subject as above.

2. Reference la forwarded an Item Description to PM-CIE which was to be used to initiate a Supply Request Package for the above visors (SPH-4B, dual visor configuration). A similar Item Description for laser protective visors for the SPH-4 (single visor configuration) was later forwarded to support Operation Desert Shield. The latter Item Description was changed to a Military Specification format, (reference lb), at the request of Defense Personnel Support Center (DPSC). PM-CIE requested that the original item description also be changed to specification format (reference lc), as DPSC will also procure the dual visor configuration.

3. The Laser Protective Visors for the SPH-4B Aviator's Helmet consist of two visor assemblies, a light laser protective visor assembly for night use that provides two wavelengths of protection, and a dark laser protective visor assembly for day use that provides three wavelengths of protection. The visors are intended to be used with the Gentex Dual Visor Assembly (DVA), a component of the SPH-4B Aviator's Helmet. The dark visor will be used in the outside visor position and the light visor will be used in the inside visor position. As the SPH-4B has been Type Classified an "interim" helmet pending the fielding of the Aircrew Integrated Helmet System 9HGU-56), the preparation of a complete specification and Technical Data Package is not warranted. The changes cited to the visor specification are for a "one-time" procurement action, and cited changes should not be used for any procurement other than the action intended.

4. The Laser Protective Visors for the SPH-4B Aviator's Helmet are to be procured in accordance with Military Specification MIL-V-43511, Revision C: Visors, Flyer's Helmet, Polycarbornate dated 16 July 1990 with the following one time changes:

a. Page 1, para 1.2 Classification: References to Class I, Class 2 and Class 2G do not apply. Delete "in entirety".

b. Page 2, para 2.1.1 Specification, standards and handbooks: Add under Specifications, Military - "MIL-S-44366 - Spectacles, Protective, Laser, Ballistic".

c. Page 3, para 2.2 Non-Government publications: Add: "ANSI Z80.3-1986 - Requirements for Nonprescription Sunglasses and Fashion Eyewear (Application for copies of ANSI publication should be addressed to ANSI, 1430 Broadway, New York, NY 10018)".

d. Page 3, para 3.2 Design and dimensions: Delete "in entirety" and substitute "The light laser protective visor's design and dimensions shall be in accordance with Gentex Part Number 87C7443, Visor, Inner; and the dark laser protective visor's design and dimensions shall be in accordance with Gentex Part Number 87C7442, Visor, Outer; or otherwise compatible with the Gentex Dual Visor Assembly, Gentex Part Number 90C7930".

e. Page 4, para 3.5.3.1 Class 1 visor: Delete "in entirety" and substitute "Luminous transmittance (scotopic). The scotopic luminous transmittance of the laser protective visors (for dark adapted eye) assuming CIE Standard Illuminant C shall be not less than 40% for the light laser protective visor and not less than 9% for the dark laser protective visor when tested as specified in 4.4.5".

f. Page 4, para 3.5.3.2 Class 2 visor: Delete " in entirety" and substitute "Luminous transmittance (photopic). The photopic luminous transmittance of the laser protective visors, assuming CIE Standard Illuminate C, shall not be less than 40% for the light laser protective visor and not less than 10% for the dark laser protective visor when tested as specified in 4.4.5".

g. Page 4, para 3.5.4 Optical density & para 3.5.4.1 Class 2G visor: Delete "in entirety" and substitute "Optical density. The light laser protective visor shall have minimum optical densities (OD) of 4 at 694.3 nm and 4 at 1064 nm for laser radiation incident normal to the substrate with any polarization state. The dark laser protective visor shall have minimum optical densities of 4 at 532 nm, 4 at 694.3 nm and 4 at 1064 nm for laser radiation incident normal to the substrate with any polarization state when tested as specified in 4.4.5".

h. Page 5, para 3.5.7 Ultraviolet transmittance: Delete "in entirety" and substitute "Ultraviolet absorption". The visors shall absorb at least 90% of the incident ultraviolet radiation (290 to 380 nm as defined in ANSI Z80.3-1986 section 3.9.2) when tested as specified in 4.4.5".

i. Page 5, para 3.5.8 Neutrality of class 2 and 2G visors: Delete "in entirety" and substitute "High energy laser. The laser protective visor shall meet the optical density requirements specified when tested against a radiant exposure of 20 milliJouls per square centimeter for Q-switched emissions less than 40 nanoseconds and greater than 1 nanosencond when tested as specified in 4.4.5".

j. Page 5, para 3.5.9 Chromaticity of classes 2 and 2G visors: Delete "in entirety" (see para 3a).

k. Page 8, para 4.4.5 End item testing: Delete "in entirety" and substitute "The visors shall be tested for the characteristics listed in table II. The sample unit for all tests shall be one visor. The inspection level for all tests except for Impact resistance, Abrasion resistance and High energy laser shall be S-3. The inspection level shall be S-1 for Impact resistance, S-1 for Abrasion resistance and S-1 for High energy laser.

l. Page 8, TABLE II. End item tests

1. for Characteristic :Luminous transmittance", under Number Determinations: Delete "in entirety" and substitute "2/unit".

2. For Characteristic "Optical density" under Results delete "1%" and substitute "Pass of fail".

3. Under Characteristic: Delete "Ultraviolet 1/transmittance" and substitute "Ultraviolet absorption".

4. Under Characteristic: Delete "Neutrality of class 2 & 2G" and substitute "High energy laser", under Results delete "1%" and substitute "Pass or fail".

5. Under Characteristic: Delete "Chromaticity of class 2 &2G", under Requirement delete "3.5.9" under Test Method delete "4.5.9", under Number Determination delete "1/unit" and under Results delete "1%".

m. Page 8, li~~nes 3 thru 7~~: Delete footnote 1/ "in entirety".

n. Page 10, para 4.5.3 Luminous transmittance test: Delete "in entirety" and substitute "Shall be measured in accordance with TABLE II and paragraph 4.5.2.9 of MIL-S-44366. Photopic and scotopic will be measured in accordance with paragraphs 4.5.2.9.1 and 4.5.2.9.2 of MIL-S-44366".

o. Page 10, para 4.5.4 Optical density of class 2G test: Delete "in entirety" and substitute "Optical density. Shall be tested at point C in accordance with TABLE II of MIL-V-43511 and para 4.5.2.6.1 or 4.5.2.6.2 of MIL-S-44366".

p. Page 11, para 4.5.7 Ultraviolet transmittance test: Delete "in entirety" and substitute "Ultraviolet absorption. Shall be tested in accordance with TABLE II of MIL-V-43511 and para 4.5.2.5 of MIL-S-44366".

q. Page 11, para 4.5.8 (and TABLE III) Neutrality of class 2 and 2G visors test: Delete "in entirety" and substitute "High energy laser. Shall be tested in accordance with paras 4.5.2.7, 4.5.2.7.1, 4.5.2.7.2, 4.5.2.7.3 and 4.5.2.7.4 of MIL-S-44366".

r. Page 12, para 4.5.9 and TABLE IV Chromaticity of class 2 & 2G visors test: Delete "in entirety" (see 3a & 3j).

5. The annotated changes presented in this document shall supersede all previous messages on subject items. Point of contact on the procurement document format is Mr. Barry Hauck, DSN 256-4097. Questions involving technical content should be addressed to Mr. Harold Moody, DSN 256-5580.
-- The Soldiers' Command

FOR THE COMMANDER:

Original Signed

DENNIS GORDON
Director, Engineering Programs
Management Directorate

H. Moody, Armor Sec, IPD

C, Armor Sec, IPD

C, A&SP Br, IPD

C, LSSD, IPD

CF:
Cdr, DPSC, DPSC-FS
PM-CIE
Natick Liaison (Mr. Paci)
QAM Br, EPMD

7.10. Appendix 10.

IHDS fit/comfort evaluation form

Integrated helmet display system fit/comfort evaluation form

Test Subject Data

Name/Rank: ____________________ Date: _______________

Unit: _______________ Phone #: ______________________________

Primary helmet type: SPH-4 SPH-4B IHADSS Cobra (Circle one)

Helmet size: __________

Primary aircraft type: UH-60 AH-64 UH-1 AH-1 OH-58 CH-47 (Circle one)

Primary crew station: Pilot Co-pilot/Gunner (Circle one)

Accumulated flight hours: __________

Approximate hours on ANVIS-6: __________ Approximate hours on PVS-5: ___________

Approximate hours on IHADSS HDU at night: ___________

ANTHROPOMETRY (measurements in cm):

1. Ectocanthus - back of head (left): ______ (right): ______
2. Ectocanthus - top of head (left): _______ (right): ______
3. Glabella to wall: ___________
4. Head breadth: ____________
5. Head Circumference: ___________
6. Head length: ____________
7. Interpupillary breadth: __________
8. Tragion - back of head (left): _________ (right): ________
9. Tragion - top of head (left): ________ (right): _________

Integrated helmet display system fit/comfort evaluation form
(Continued)

Length of time worn in simulator: ________

Number of IHDS adjustments made in simulator: ________

Number of times IHDS as removed during simulation flight: ______

---

1. IHDS size: ____________

2. Time required to obtain adequate fit: ____________

PLEASE CIRCLE AND COMMENT ON THE FOLLOWING QUESTIONS PERTAINING TO THE IHDS:

3. Rate the ease of donning the IHDS.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

4. Rate the ease of adjusting the IHDS earcups.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

5. Rate the ease adjusting the IHDS retention system.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

Integrated helmet display system fit/Comfort evaluation form
(Continued)

6. Rate the ease of adjusting the IHDS optical system.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

7. Rate the ease of doffing the IHDS.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

8. Rate the overall comfort of the IHDS.

Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable
1	2	3	4	5

Comments:____

____

9. Did you experience any pressure points (hot spots)?

Yes No

9a. If yes, please illustrate its location(s) below.

9b. If yes, please rate the intensity level experienced.

Barely Noticeable	Moderately Noticeable	Significant Pain	Excruciating Pain	Had to Remove
1	2	3	4	5

Comments:____

____

Integrated helmet display system fit/comfort evaluation form
(Continued)

10. Did you experience any heat build up?

Yes No

Comments:____

11. Rate the overall fit of the IHDS.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

12. Rate the comfort of the earcups and earseals.

Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable
1	2	3	4	5

Comments:____

13. Rate the IHDS in terms of perceived sound attenuation.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

14. Rate the IHDS in terms of perceived speech intelligibility.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

Integrated helmet display system fit/comfort evaluation form
(Continued)

15. Rate the comfort of the chin strap.

Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable
1	2	3	4	5

Comments:____

16. Rate your perceived effectiveness of the chin strap.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

17. Rate the comfort of the nape strap.

Very Uncomfortable	Uncomfortable	Neutral	Comfortable	Very Comfortable
1	2	3	4	5

Comments:____

18. Rate your perceived effectiveness of the nape strap.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

19. Rate your perceived weight of the IHDS when worn.

Very Heavy	Heavy	Borderline	Light	Very Light
1	2	3	4	5

Comments:____

Integrated helmet display system fit/comfort evaluation form
(Continued)

20. Rate your perceived balance (center-of-mass) of the IHDS when worn.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

____

21. How much neck strain did you experience?

Maximal	Strong	Moderate	Slight	None
1	2	3	4	5

Comments:____

____

22. Rate the ease of head movement when wearing the IHDS.

Unacceptable	Poor	Borderline	Good	Excellent
1	2	3	4	5

Comments:____

____

23. Rate the IHDS stability during vertical head movement (quickly moving your head to look up or down).

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

____

24. Rate the IHDS stability during horizontal head movement (quickly moving your head to look left or right).

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

____

Integrated helmet display system fit/comfort evaluation form
(Continued)

25. Rate the IHDS in terms of lateral field-of-view.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

____

26. Rate the IHDS in terms of vertical field-of-view.

Very Poor	Poor	Borderline	Good	Very Good
1	2	3	4	5

Comments:____

____

27. Rate the ease of visor operation.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

28. Rate the ease of attaching optical components.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

29. Rate the ease of detaching optical components

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

____

Integrated helmet display system fit/comfort evaluation form
(Continued)

30. Rate the stability of optical components.

Very Difficult	Difficult	Neutral	Easy	Very Easy
1	2	3	4	5

Comments:____

31. Rate the IHDS crewstation compatibility.

Very Unacceptable	Unacceptable	Neutral	Acceptable	Very Acceptable
1	2	3	4	5

Comments:____

32. Rate the IHDS overall acceptability.

No Way!!	Reluctantly	Neutral	Easy	Gotta have it!!
1	2	3	4	5

Comments:____

33. What is wrong with the IHDS?

34. What changes/improvements/enhancements do you recommend?

35. Please review the questions asked. Add your comments here on any issues that were not addressed.

7.11. Appendix 11.

Safety hazard log form

EQUIPMENT: **DATE:**

HAZARD NO:

HAZARD CLASSIFICATION:

HAZARD DESCRIPTION:

RECOMMENDED ACTION:

REMARKS:

7.12. Appendix 12.

Field evaluation initial inspection checklist

Test Title:____________ Date:___________

TECOM Project No. ____________

	Yes	No	N/A
1. Are the packages, containers, or crates correctly labeled in accordance with the shipping documents?	___	___	___
2. Does the label on the test item correspond to the shipping documents?	___	___	___
3. Is the test item arrival condition and mode of transportation satisfactory?	___	___	___
4. Is the general condition of all boxes and containers acceptable?	___	___	___
5. Do shipping cartons have appropriate warning and caution labels?	___	___	___
6. Is there visible damage to the test item prior to unpacking?	___	___	___
7. Is the test item damaged?	___	___	___
8. Does the test item (quantity, serial number, etc.) agree with the packing list provided by the test sponsor?	___	___	___
9. Has the test item been inspected in accordance with the operator and organizational technical manuals provided with the system or other best source data available?	___	___	___
10. Has the test item been inspected for safety hazards?	___	___	___
11. Have all receipt checks or procedures been conducted as outlined in the technical manuals or other best source documentation available?	___	___	___
12. Have the test items been photographed?	___	___	___

	Yes	No	N/A
13. Inspect the SSP for the following:			
a. Is there visible damage to the SSP prior to unpacking?	___	___	___
b. Are the items in the SSP damaged?	___	___	___
c. Do the components of the SSP agree with those listed in TOP 7-3-507:			
(1) Draft equipment publications?	___	___	___
(2) Personnel requirements?	___	___	___
(3) Training requirements?	___	___	___
(4) Support requirements?	___	___	___
(5) Tools (common, special)?	___	___	___
(6) Description of the maintenance concept?	___	___	___
d. Do the components of the SSP agree with the SSP checklist provided with the equipment?	___	___	___
e. Has the SSP been photographed?	___	___	___
f. Have the items in the SSP been inspected in accordance with the operator and organization technical manuals provided with the system or other best source data available?	___	___	___
14. Are all discrepancies documented?	___	___	___

REMARKS: ____

____

____

____

7.13. Appendix 13.

IHDS utilization log

Name/Rank:____________ Duty Phone:_______

IHDS Serial No.__________ Week Ending_______

Crew Position __________

Date	Hours IHDS Was Used	Type of Mission and Tasks Performed
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________
____	______	______________________

7.14. Appendix 14.

Supportability analysis chart

SUPPORTABILITY ANALYSIS CHART TECOM TOP 7-3-507		PROJECT NO.				NOMENCLATURE					IDENTIFICATION NO.
GP NO. (SEQ NO.)	COMPONENT AND RELATED OPERATIONS	MAINTENANCE LEVEL O-AVUM I-AVIM D-DEPOT		TM INSTRUCTIONS		ACTIVE MAINTENANCE TIME		NUMBER OF MEN	SYSTEM LIFE H-HOURS M-MILES R-ROUND	REASON PERFORMED	REMARKS
		PRESS	RECM	ADQT	INADQT	CLOCK HOURS	MAN HOURS				
1	2	3	4	5	6	7		8	9	10	11

EBG Form 1033, 1 Jun 84, Supersedes EBG Form 1033, 1 Jan 83, which will be used until supply exhausted.

7.15. Appendix 15.

Supportability design checklist

Design Considerations	Yes	No	N/A	Comments
1. Have the amount, frequency, and complexity of required maintenance tasks been minimized?				
2. Have the levels of maintenance skills and associated training requirements been minimized?				
3. Have the frequency and extent of preventive maintenance been established?				
4. Is special operator or maintenance training required?				
5. Have volume and complexity of maintenance publications been minimized?				
6. Do characteristics of the commodity and its components provide minimum down time?				
7. Are maintenance technical data available with equipment?				
8. Does design allow for rapid and positive identification of equipment malfunction or marginal performance?				
9. Can components which need replacing or repairing be rapidly identified?				
10. Have the quantities and type of tools and equipment necessary to maintain the whole commodity been summarized?				
11. Has the need for special tools been minimized?				
12. Are parts replacements and repair consistent with MAC and DTM?				

7.16. Appendix 16.

Supply support chart

SUPPLY SUPPORT CHART TECOM TOP 7-3-507		PROJECT NO.	NOMENCLATURE				IDENTIFICATION
GP NO. (SEQ NO.)	NATIONAL STOCK NUMBER	NOUN NOMENCLATURE	MAINTENANCE LEVEL O-AVUM I-AVIM D-DEPOT		PART LIFE H-HOURS M-MILES R-ROUNDS	REASON USED	REMARKS
			PRES B	RECM			
1	2	3	4	5	6	7	8

EBG Form 1031, 1 Jun 84, Supersedes EBG Form 1031, 1 Jan 83, which will be used until supply exhausted.

7.17. Appendix 17.

DA form 2028
Recommended changes to publications and blank forms

RECOMMENDED CHANGES TO PUBLICATIONS AND BLANK FORMS For use of this form, see AR 25-30; the proponent agency is ODISC4.	Use Part II *(reverse)* for Repair Parts and Special Tool Lists (RPSTL) and Supply Catalogs/Supply Manuals (SC/SM).	DATE
TO: *(Forward to proponent of publication or form) (Include ZIP Code)*	FROM: *(Activity and location) (Include ZIP Code)*	

PART I - ALL PUBLICATIONS (EXCEPT RPSTL AND SC/SM) AND BLANK FORMS

PUBLICATION/FORM NUMBER	DATE	TITLE

ITEM NO.	PAGE NO.	PARA-GRAPH	LINE NO.*	FIGURE NO.	TABLE NO.	RECOMMENDED CHANGES AND REASON *(Provide exact wording of recommended change, if possible).*

Reference to line numbers within the paragraph or subparagraph.

TYPED NAME, GRADE OR TITLE	TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION	SIGNATURE

DA FORM 1 FEB 74 2028 REPLACES DA FORM 2028, 1 DEC 65, WHICH WILL BE USED.

TO: *(Forward direct to addressee listed in publication)*	FROM: *(Activity and location) (Include ZIP Code)*	DATE

PART II - REPAIR PARTS AND SPECIAL TOOL LISTS AND SUPPLY CATALOGS/SUPPLY MANUALS

PUBLICATION NUMBER	DATE	TITLE

PAGE NO.	COLM NO.	LINE NO.	NATIONAL STOCK NUMBER	REFERENCE NO.	FIGURE NO.	ITEM NO.	TOTAL NO. OF MAJOR ITEMS SUPPORTED	RECOMMENDED ACTION

PART III - REMARKS *(Any general remarks or recommendations, or suggestions for improvement of publications and blank forms. Additional blank sheets may be used if more space is needed.)*

TYPED NAME, GRADE OR TITLE	TELEPHONE EXCHANGE/AUTOVON, PLUS EXTENSION	SIGNATURE

☆U.S. Government Printing Office: 1989-242-450/90283

7.18. Appendix 18.

Technical data/equipment publications chart

TECHNICAL DATA/EQUIPMENT PUBLICATIONS CHART TECOM TOP 7-3-507		PROJECT NO.		NOMENCLATURE					
MANUSCRIPT			DATE RECEIVED		EVALUATION		DA FORM 2028		REMARKS
NUMBER	QTY	TITLE	LIT	MATERIEL	ADQT	INADQT	DATE	FORWARDED	
1	2	3	4	5	6	7	8		9

SAMPLE

EBC Form 1034, 1 Jun 84, Supersedes EBC Form 1034, 1 Jan 83, which will be used until supply exhausted.

7.19. Appendix 19.

Support and test equipment chart

SUPPORT AND TEST EQUIPMENT CHART TECOM TOP 7-3-507	PROJECT NO.			NOMENCLATURE					
NOMENCLATURE OR DESCRIPTION	NSN OR PART NO.	MAINT LEVEL O-AVUM I-AVIM D-DEPOT		DATE RECEIVED	EVALUATION		RQR YES OR NO	TECHNICAL MANUAL IN WHICH LISTED	REMARKS
		PRES B	RECH		ADQT	INADQT			
1	2	3	4	5	6	7	8	9	10

SAMPLE

EBG Form 1032, 1 Jun 84, Supersedes EBG Form 1032, 1 Jan 83, which will be used until supply exhausted.

7.20. Appendix 20.

Flight crew anthropometric data sheet

Name________________________________ Date________________ __

Measure	Measurement	Percentile
Height	________	________
Weight	________	________
Head Circumference	________	________
Sagittal Arc	________	________
Bitragion-Coronal Arc	________	________
Head Length	________	________
Nasal Root-Wall	________	________
Pronasale-Wall	________	________
Ectocanthus-Wall	________	________
Tragion-Wall	________	________
Head Breadth	________	________
Head Height	________	________
Glabella-Vertex Height	________	________
Face Length	________	________
Interpupillary Breadth	________	________
Hand Circumference	________	________
Hand Breadth	________	________
Hand Thickness	________	________

7.21. Appendix 21.

HFE observation data sheet

Date ____________________ Test Item ________________ No. ___________

Data Collector: ____

Test Conditions: Day ___ Night ___ NVS ___ Other ____________________

Test Participant: ____

Observation Data: ____

____

____

____

____

____

____

____

____

Participant Comments: ____

____

____

____

Follow-up Action: ____

____

____

Safety Issue: __ Yes __ No
Test Incident Report Required __ Yes __ No
Photo Required: __ Yes __ No

(USE OTHER SIDE FOR DIAGRAMS, SKETCHES, ETC.)

USE FOR DIAGRAMS, SKETCHES, ETC.

7.22. Appendix 22.

HFE 4-hour wear assessment interview guide

Name ______________________________ Date ________________

ISSUE	COMMENTS

IHDS fit-

Fit retention-

Comfort-

Helmet "hot spots"-

Adjustment capability-

Speech intelligibility-

Noise attenuation-

Depth perception-

Visual disorientation-

Fatigue-

Additional comments:

7.23. Appendix 23.

IHDS flight performance assessment record

Instructor Pilot ____________ Pilot ______________ Date ____________

Mission Profile: Day ___ Night ___ Adverse Weather ___

Task Scale: 5 Very Good 3 Borderline 1 Very Poor
4 Good 2 Poor

TASK LIST	IP RATING	COMMENTS
1. Start, runup, T/O checks	____	____________________
2. Ground taxi	____	____________________
3. Hovering flight	____	____________________
4. Normal takeoff	____	____________________
5. High speed flight	____	____________________
6. High/low g flight	____	____________________
7. Traffic pattern	____	____________________
8. VMC approach	____	____________________
9. Rolling takeoff	____	____________________
10. Rolling landing	____	____________________
11. Slope operations	____	____________________
12. Terrain flight	____	____________________
13. Terrain flight decel	____	____________________
14. Terrain flight approach	____	____________________
15. Confined area operations	____	____________________

7.23. Appendix 23. (Continued)

TASK LIST	IP RATING	COMMENTS
16. Search and acquire target	____	____________________
17. Target engagement	____	____________________
18. IMC flight (using only IHDS)	____	____________________

Additional Comments:

____

AIS life support equipment Configuration: A __ B __

7.24. Appendix 24.

IHDS/weapon system integration assessment record

Instructor Pilot ____________________ Pilot _____________________

Date _____________

Mission Profile: Day ___ Night ___ Adverse Weather ___

Sensor: Forward-looking infrared (FLIR) ___
Image intensifier (I^2) ___

	Rocket	Missile	ATAS	Gun
Image Quality	_____	_____	_____	_____
Registration	_____	_____	_____	_____
Magnification	_____	_____	_____	_____
FOV	_____	_____	_____	_____
Sensor Slew Rate	_____	_____	_____	_____
Sensor/Pilot Offset	_____	_____	_____	_____

Additional Comments:

7.25. Appendix 25.

HFE questionnaire

Name ______________________________ Date __________________

Total Flight Hours _____________ Total IHDS Hours _________________

Total AN/AVS-6 Hours ___________

1. Please rate the fit of the IHDS.

   __5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

2. Please rate the comfort of the IHDS.

   __5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

3. Please rate the IHDS range of adjustment.

   __5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

4. Did you experience any problems involving fit retention of the IHDS?

   Yes___ No___

If yes, please explain: ____________________________________

5. Please rate the IHDS donning and doffing procedures.

   __5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

6. Please rate the IHDS boresight requirements/retention.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

____

7. Please rate the quality of the HMD FLIR image to perform the following tasks:

a. Taxi.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

b. Takeoff.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

c. Navigation.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

d. Confined area operations.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

e. NOE.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

f. High speed flight.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

g. Detection.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

h. Identification.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Appendix 25. (Continued)

I. Avoidance.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

j. Target engagement.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

k. Formation flight.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

l. Landing.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

8. Please rate the quality of the IHDS I^2 system to perform the following tasks:
a. Taxi.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

b. Takeoff.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

c. Navigation.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

d. Confined area operations.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

e. NOE.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

f. High speed flight.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

g. Detection.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

h. Identification.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

I. Avoidance.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

j. Target engagement.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

k. Formation flight.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

l. Landing.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

9. Please rate the contrast between displayed information and the FLIR image background.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

____

10. Please rate the contrast between displayed information and the I^2 background.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

____

Appendix 25. (Continued)

11. Please rate the FLIR/I^2 image contrast adjustment capability.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comment: ____

____

12. Please rate the resolution of the HMD image while the turret was traversing.

FLIR Image	I^2 Image
__5 Very Good	__5 Very Good
__4 Good	__4 Good
__3 Borderline	__3 Borderline
__2 Poor	__2 Poor
__1 Very Poor	__1 Very Poor

Comments: ____

____

13. Please rate the time interval when switching from FLIR to I^2 imagery.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

____

14. Did the aircraft internal lighting affect your ability to utilize FLIR/I^2 imagery?

Yes___ No___

If yes, please explain: ____

____

15. Please rate the FLIR/I^2 imagery response to external bright lights that occur during flight operations.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____

____

Appendix 25. (Continued)

16. Please rate the size of symbology presented.

FLIR Image	I^2 Image
__5 Very Good	__5 Very Good
__4 Good	__4 Good
__3 Borderline	__3 Borderline
__2 Poor	__2 Poor
__1 Very Poor	__1 Very Poor

Comments: ____
____

17. Were all the symbols presented on the FLIR/I^2 imagery easy to understand?

Yes___ No___

If no, please explain: ______________________________________

18. Did you experience any spatial disorientation problems while viewing the FLIR/I^2 imagery?

Yes___ No___

If yes, please explain: ______________________________________

19. Did you experience any discrepancies between the perceived and actual size and/or distance of an object viewed through the HMD.

Yes___ No___
If yes, please explain: ______________________________________

20. Does the difference between sensor location and eye location create problems with obstacle clearance?

Yes___ No___
If yes, please explain: ______________________________________

Appendix 25. (Continued)

21. Please list any HMD symbology you feel is distracting or unnecessary and should therefore be eliminated. Please include a rationale for each symbol.

Symbology　　　Rationale

22. Did you experience any safety related problems while using the IHDS during flight operations?

Yes___ No___

If yes, please explain: ____
____

23. Additional Comments: ____
____
____
____

7.26. Appendix 26.

Support/maintenance personnel anthropometric data sheet

Name ______________________________ Date ___________________

Measure	Measurement	Percentile
Height	__________	__________
Weight	__________	__________
Functional Arm Reach	__________	__________
Vertical Arm Reach	__________	__________
Hand Circumference	__________	__________
Hand Breadth	__________	__________
Hand Thickness	__________	__________

7.27. Appendix 27.

Design for maintainability checklist

Test Title ______________________________ Date __________

TECOM Project No. ____________________________________

Detailed Design Considerations	SAT	UNSAT	REMARKS
1. Equipment uses standard parts to the extent possible. (MIL-STD-1472D, para 5.9.1.1)	___	___	___________
2. Equipment is replaced in modular packages. Assemblies and modules should be mounted such that replacing one does not require removal of others. (MIL-STD-1472D, para's 5.9.1.3 and 5.9.2.1)	___	___	___________
3. Equipment can be rapidly and easily removed and replaced by one person, within weight limitations contained in MIL-STD-1472D, para 5.9.1.3.	___	___	___________
4. Unitized functions allow each item to be checked and adjusted separately. (MIL-STD-1472D, para 5.9.1.4)	___	___	___________
5. Equipment is designed to facilitate rapid and positive fault detection and isolation. (MIL-STD-1472D, para 5.9.1.5)	___	___	___________
6. Equipment is designed for easy assembly and disassembly. (MIL-STD-1472D, para 5.9.1.8)	___	___	___________

Detailed Design Considerations	SAT	UNSAT	REMARKS
7. Equipment can be removed, replaced, and repaired wearing personal and special purpose clothing and equipment, if applicable. (MIL-STD-1472D, para 5.9.1.7)	___	___	___________
8. Similar components cannot be physically interchanged unless functionally the same. (MIL-STD-1472D, para 5.9.1.8a)	___	___	___________
9. Components cannot be improperly mounted. (MIL-STD-1472D, para 5.9.1.8b)	___	___	___________
10. Coding, etc., is used for easy identification of components. (MIL-STD-1472D, para 5.9.1.8c)	___	___	___________
11. Alignment pins, etc., are used for proper mounting of components. (MIL-STD-1472D, para 5.9.1.8d)	___	___	___________
12. Cables and connectors are designed for easy identification, orientation, and alignment. (MIL-STD-1472D, para 5.9.1.8e)	___	___	___________
13. Parts are mounted so that a lower layer does not support an upper layer. (MIL-STD-1472D, para 5.9.2.1)	___	___	___________
14. Similar, but not functionally related, items are mounted with a standard orientation but are readily identifiable and distinguishable. (MIL-STD-1472D, para 5.9.2.2)	___	___	___________

Appendix 27. (Continued)

Detailed Design Considerations	SAT	UNSAT	REMARKS
15. Delicate items are located or guarded so they aren't susceptible to damage during service. (MIL-STD-1472D, para 5.9.2.3)	___	___	___________
16. Maintenance controls comply with para 5.4, controls; and para 5.5, labeling; of MIL-STD-1472D, para 5.9.3.	___	___	___________
17. Knobs are used for calibration controls when frequent adjustments must be made. (MIL-STD-1472D, para 5.9.3.1)	___	___	___________
18. Screwdriver adjustments made without the aid of vision are designed to preclude screwdriver slipping. (MIL-STD-1472D, para 5.9.3.2)	___	___	___________
19. Reference scales or other feedback methods are available and visible for all adjustment controls. (MIL-STD-1472D, para 5.9.3.3)	___	___	___________
20. Adjustment or calibration controls with limited degree of motion have mechanical stops that prevent damage. (MIL-STD-1472D, para 5.9.3.4)	___	___	___________
21. Sensitive adjustment points are guarded against inadvertent movement. (MIL-STD-1472D, para 5.9.3.5)	___	___	___________
22. Internal controls are not located close to dangerous voltage, rotating machinery, or other hazards without shielding and labeling. (MIL-STD-1472D, para 5.9.3.6)	___	___	___________

Appendix 27. (Continued)

Detailed Design Considerations	SAT	UNSAT	REMARKS
23. Structural members do not prevent access to or removal of items. (MIL-STD-1472D, para 5.9.4.1)	___	___	___________
24. Replaceable items are not mounted so that they are difficult to remove. (MIL-STD-1472D, para 5.9.4.1)	___	___	___________
25. The removal of panels, cases, and covers is not blocked by structural members or other items. (MIL-STD-1472D, para 5.9.4.1)	___	___	___________
26. Large, difficult to remove items do not prevent convenient access to other items. (MIL-STD-1472D, para 5.9.4.2)	___	___	___________
27. Checkpoints, adjustment points, test points, cables, etc., are accessible and visible during maintenance. (MIL-STD-1472D, para 5.9.4.3)	___	___	___________
28. Space exists for the use of test equipment and other tools. (MIL-STD-1472D, para 5.9.4.3)	___	___	___________
29. Equipment requiring rear access is free to open or rotate the full distance and remain in the open position without hand support. (MIL-STD-1472D, para 5.9.4.4)	___	___	___________
30. Aircraft installed equipment shall be configured for one-sided access. (MIL-STD-1472D, para 5.9.4.4)	___	___	___________

Appendix 27. (Continued)

Detailed Design Considerations	SAT	UNSAT	REMARKS
31. Critical items requiring rapid maintenance are most accessible. (MIL-STD-1472D, para 5.9.4.5)	___	___	___________
32. Items requiring most frequent access, when criticality is not an issue, are most accessible. (MIL-STD-1472D, para 5.9.4.5)	___	___	___________
33. High-failure-rate items are replaceable without having to remove other items. (MIL-STD-1472D, para 5.9.4.6)	___	___	___________
34. Mechanical items are removable with common tools. (MIL-STD-1472D, para 5.9.4.6)	___	___	___________
35. Access to equipment does not require removal of equipment maintained by another technician. (MIL-STD-1472D, para 5.9.4.7)	___	___	___________
36. Installation of the system does not deny access to other aircraft systems requiring service or maintenance.	___	___	___________
37. Tools and test equipment for maintenance, repair, or checkout at AVUM level are minimal.	___	___	___________
38. The equipment is designed such that all line replacement units are replaceable at the AVUM level.	___	___	___________

Appendix 27 . (Continued)

Detailed Design Considerations	SAT	UNSAT	REMARKS
39. Equipment is designed to assure that all preventive and corrective maintenance tasks can be performed by Army personnel with a skill level equivalent to that of an Army maintenance school graduate with 6 months on-the-job experience.	___	___	___________
40. Equipment is designed to assure that no more than two maintenance personnel are required to perform any corrective maintenance tasks at AVUM.	___	___	___________
41. A capability for fault detection and location is provided by use of a subsystem/component built-in test.	___	___	___________

7.28. Appendix 28.

HFE maintenance questionnaire

Name ______________________ Date ________________

Rank ______________________ MOS ________________

Years Experience ____________

1. Please rate the access to IHDS parts, components, or equipment.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____
____

2. Please rate the process of removing IHDS parts, components, or equipment.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____
____

3. Please rate the process of isolating faults within a IHDS line removable unit.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____
____

4. Please rate the process of correcting faults within an IHDS line removable unit.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____
____

5. Did you experience any problems involving the labeling/ identification of circuit board slots within a line removable unit?

Yes___ No___
If yes, please explain: ________________________________

6. Did you experience any problems involving the labeling/identification of cables and terminal connections?

Yes___ No___

If yes, please explain: ____
____

7. Please rate the process of system checkout upon completion of corrective maintenance procedures.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____
____

8. Could all required service and maintenance procedures be performed using the tools in the standard mechanics' or electricians' tool box?

Yes___ No___

If no, please explain: ____
____

9. Please rate the publications provided which describe IHDS maintenance operations.

__5 Very Good __4 Good __3 Borderline __2 Poor __1 Very Poor

Comments: ____
____

10. Could all required service and maintenance procedures be performed while wearing NBC protective equipment?

Yes___ No___

If no, please explain: ____
____

Appendix 28. (Continued)

11. Could all required service and maintenance procedures be performed while wearing arctic protective equipment?

Yes___ No___

If no, please explain: ____

____

12. Did you experience any safety related problems while performing maintenance operations?

Yes___ No___

If yes, please explain: ____

____

13. Additional comments: ____

____

____

____

7.29. Appendix 29.

Emergency egress data sheet

Name ________________________ Date ________________

AIS life support equipment Configuration A

Trial	Time	Trial	Time
1	____	2	____
3	____	4	____

Problems/Observations:

Photograph Required ___

Test Incident Report Required ___

Safety Issue ___

AIS life support equipment Configuration B

Trial	Time	Trial	Time
1	____	2	____
3	____	4	____

Problems/Observations:

Photograph Required ___

Test Incident Report Required ___

Safety Issue ___

7.30. Appendix 30.

Human factors maintenance safety checklist

	SAT	UNSAT	COMMENTS
1. Switches, rheostats, indicators, circuit breakers, and fuses adequately identified.	___	___	___________
2. Switches positioned to prevent inadvertent activation.	___	___	___________
3. Switch function correlates with corresponding signal light.	___	___	___________
4. Direct current input power connections clearly marked for polarity.	___	___	___________
5. Main circuit breaker located in an accessible position.	___	___	___________
6. Main power breaker Removes all power from the complete system.	___	___	___________
7. Energized components located or enclosed so that protection is provided against contact with uninsulated items.	___	___	___________
8. Electrical connectors designed to ensure correct plug can be inserted into a mating unit.	___	___	___________

Appendix 30. (Continued)

	SAT	UNSAT	COMMENTS
9. Mating plugs and receptacles coded or marked.	___	___	________________
10. Safe grounding methods furnished.	___	___	________________
11. Electrical enclosures designed for environmental factors.	___	___	________________
12. Test item designed for adequate cooling.	___	___	________________
13. Cables supported and terminated to prevent shock and fire hazards.	___	___	________________
14. Cables protected at points where they pass through metal.	___	___	________________
15. Potential electrical hazards defined in the instruction manual.	___	___	________________
16. Component edges and access openings rounded or protected to minimize injury.	___	___	________________
17. Catches, hinges, supports, and stops designed to minimize injury.	___	___	________________
18. Equipment designed for adequate center of gravity.	___	___	________________
19. Warning placards provided where mechanical hazards exist.	___	___	________________

Appendix 30. (Continued)

	SAT	UNSAT	COMMENTS
20. Potential mechanical hazards defined in the instruction manual.	___	___	___
21. Equipment can be replaced in modular packages.	___	___	___
22. Equipment designed to facilitate positive fault detection and isolation.	___	___	___
23. Components cannot be improperly mounted.	___	___	___
24. Delicate items guarded to prevent damage during service.	___	___	___
25. Adjustment or calibration controls with limited degree of motion have stops that prevent damage.	___	___	___
26. Removal of panels, cases, and covers is not blocked by structural parts.	___	___	___
27. Checkpoints, adjustment points, test points, cables, etc., are accessible during maintenance.	___	___	___
28. Space exists for the use of test equipment and tools.	___	___	___
29. Critical items requiring rapid maintenance are most accessible.	___	___	___

Appendix 30. (Continued)

	SAT	UNSAT	COMMENTS
30. High-failure-rate items are replaceable without having to remove other items.	___	___	________________
31. Access does not require the removal of equipment maintained by another technician.	___	___	________________
32. Installation of the ATHS does not deny access to other aircraft systems.	___	___	________________
33. Equipment designed so that all line replaceable units are replaceable at the AVUM level.	___	___	________________
34. Equipment designed to provide that all maintenance tasks can be performed by Army personnel with a skill level equivalent to that of an Army maintenance school graduate with 6 months on-the-job experience.	___	___	________________
35. Equipment designed so that no more than two maintenance personnel are required to perform corrective tasks at the AVUM level.	___	___	________________

7.31. Appendix 31.

Operating and support hazard analysis worksheet

Hazard description	Hazard effect	Hazard category	Comments

7.32. Appendix 32.

List of manufacturers

Ann Arbor Testing Laboratories, Inc.
Ann Arbor, MI 48106

EG&G Gamma Scientific Inc.
3777 Ruffin Rd.
San Diego, CA 92123

Gardner Laboratory, Inc.
5521 Landy Lane
P.O. Box 5728
Bethesda, MD 20014

Hewlett-Packard
3000 Hanover St.
20 DM/P.O. Box 10301
Palo Alto, CA 94303

Tektronix, Inc.
26600 SW Parkway
P.O. Box 1000
Wilsonville, OR 97070